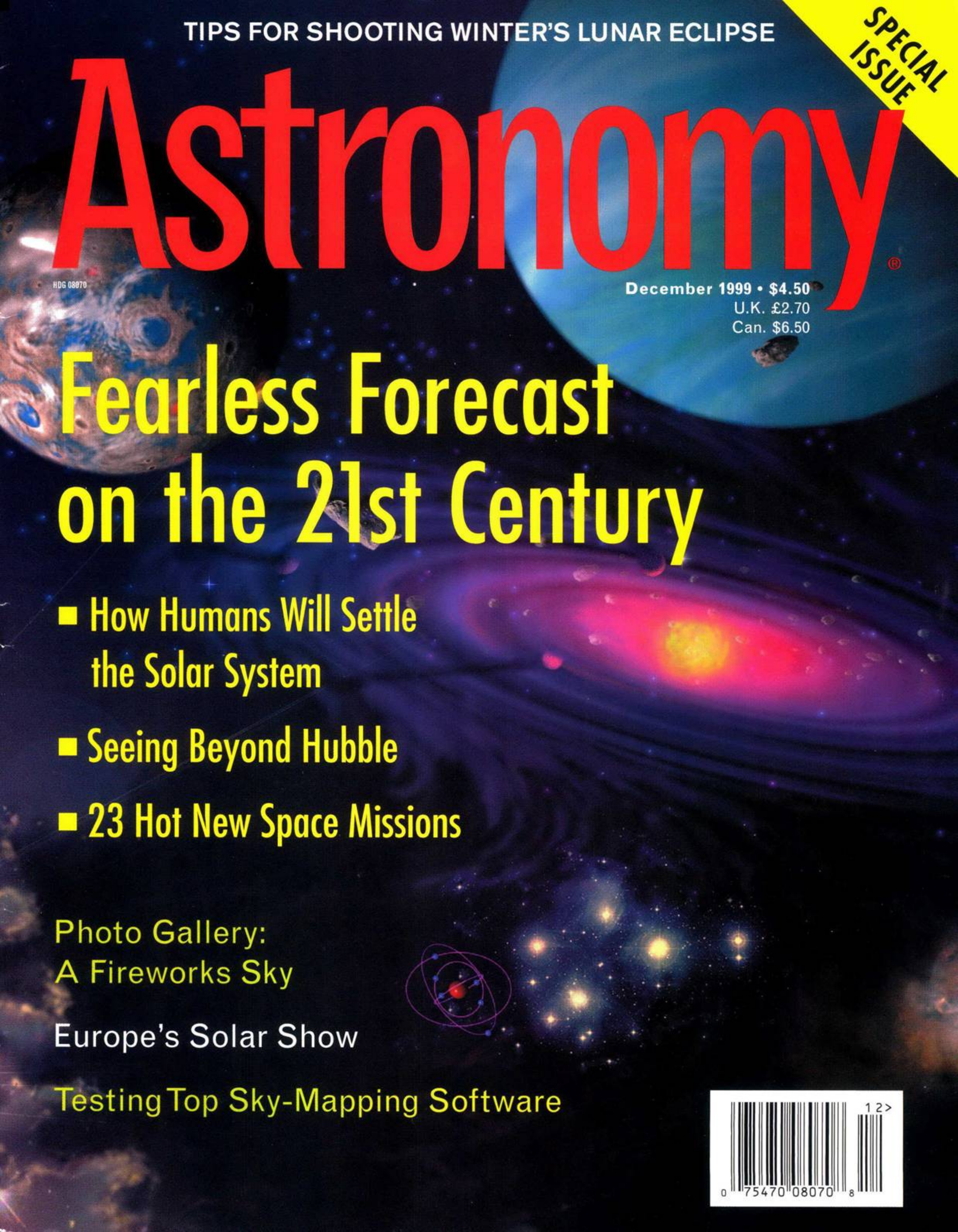

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SPECIAL ISSUE

Astronomy®

HDG 08070

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Now two ETX apertures!
ETX-90EC — $595
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Now you can buy the revolutionary Meade ETX® — the largest selling modern telescope in the world — in either of two apertures, 3.5" or 5". Both models include the very latest in microprocessor-controlled capability.

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Plus the features that created the ETX revolution:

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SPECIFICATIONS: ETX-90EC and ETX-125EC Astro Telescopes — Each includes Maksutov-Cassegrain optical tube assembly (D = 90mm, F = 1250mm, f/13.8 *or* D = 127mm, F = 1900mm, f/15) with EMC super multi-coatings; internal flip-mirror system for either straight-through or 90° observing position; fork mount with electric slow-motion controls, setting circles and locks on both axes; electronic control panel; 4-speed (8x, 32x, 0.75°/sec, 5°/sec) dual-axis motor drive system with hand controller; sidereal-rate tracking in equatorial mode with optional table tripod or deluxe field tripod; internal battery compartment accepting eight (user-supplied) AA-size batteries; 8 x 21mm erect-image (ETX-90EC) *or* 8 x 25mm right-angle (ETX-125EC) viewfinder; Series 4000 Super Plössl 26mm eyepiece (1.25"); instructions. **ETX-90EC — $595** (+ $20 packing & shipping in the 48 states); **ETX-125EC — $895** (+ $30 P & S).

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COMPUTER CONTROL
MEADE

Meade **ETX-90EC: $595** and **ETX-125EC: $895.** Each complete as shown, with electronic hand controller; plus packing and shipping.

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#880 Equatorial Table Tripod (90)	29.95
#881 Equatorial Table Tripod (125)	59.95
#883 Deluxe Field Tripod (90, 125)	199.95
#825 8 x 25mm Right-Angle Viewfinder (90)	49.95
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#932 45° Erecting Prism (90, 125)	49.95
#64 Photo Adapter (90, 125)	34.95
Electric Focuser #1244 (90) *or* #1247 (125)	119.95

**see the Meade accessory ad in this issue.*

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Orders: 800-221-0828; Info.: 718-436-6262.

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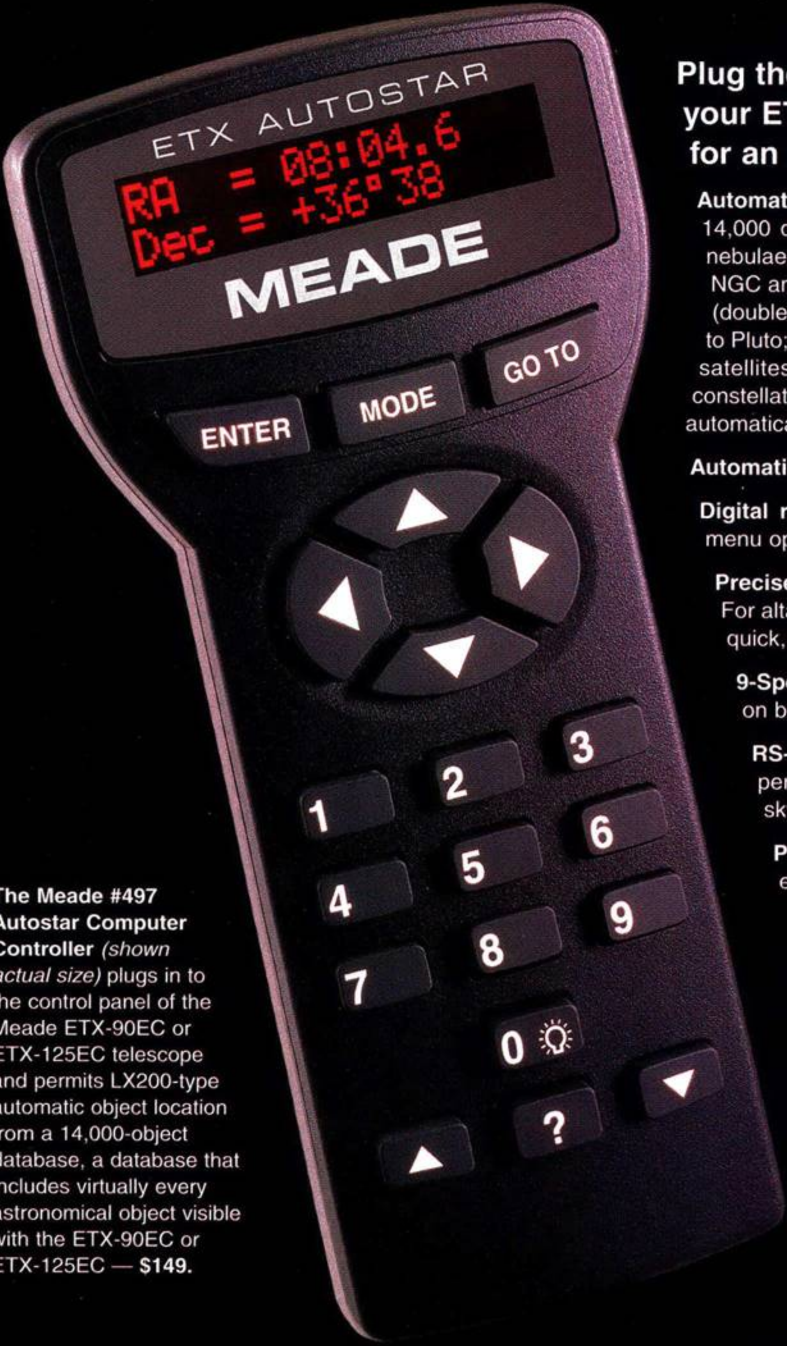
Add the Meade Autostar™ computer to your ETX-90EC or ETX-125EC for automatic GO TO object location ...only *$149!*



The Meade #497 Autostar Computer Controller *(shown actual size)* plugs in to the control panel of the Meade ETX-90EC or ETX-125EC telescope and permits LX200-type automatic object location from a 14,000-object database, a database that includes virtually every astronomical object visible with the ETX-90EC or ETX-125EC — **$149.**

Plug the #497 Autostar Computer Controller into your ETX-90EC or ETX-125EC and you're ready for an incredible array of LX200-type capabilities:

Automatic dual-axis GO TO function at 5°/sec to any of more than 14,000 database objects, including deep-space objects (galaxies, diffuse nebulae, planetary nebulae, star clusters — the best objects from the IC, NGC and Caldwell catalogs, as well as all 110 Messier objects); 900 stars (double stars, variable stars, SAO stars); the 8 major planets from Mercury to Pluto; 26 of the brightest asteroids; 15 periodic comets; 50 earth-orbiting satellites; plus user-defined objects and the centroids of all 88 constellations. Select any of these objects, press ***GO TO*** and the telescope automatically slews to the object, placing it in the telescopic field.

Automatic GO TO function to *any* object of known R.A. and Dec.

Digital readouts of telescope position (continuously in R.A. and Dec.), menu options, glossary, and utility functions.

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9-Speed Dual-Axis Operation: Pushbutton operation of the telescope on both axes, simultaneously, at any speed from 2x sidereal to 5°/sec.

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Plus: over 20 other menu options, including guided tours, major event menus, user-defined terrestrial objects, and much more.

(right) **Meade ETX-90EC,** shown with optional #497 Autostar Computer Controller plugged into the telescope's control panel.

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Patents pending on ETX-90EC, ETX-125EC, and Autostar.

December 1999 • Vol. 27, No. 12

Astronomy®

COVER ILLUSTRATION: NASA, JPL, Caltech, Pat Rawlings

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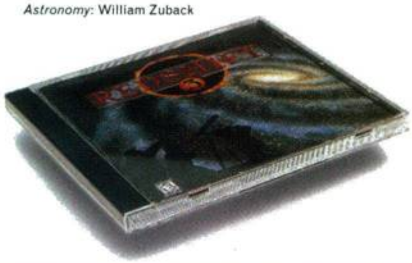

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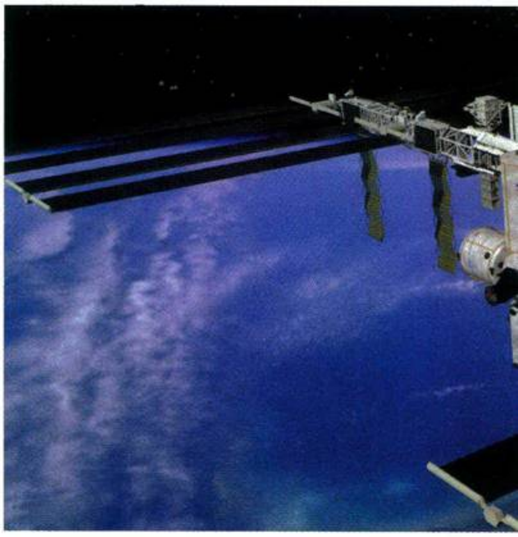

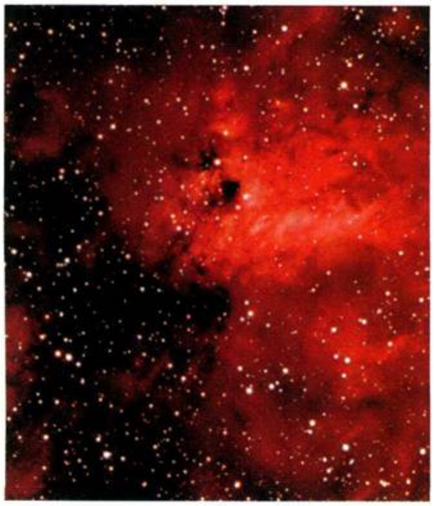

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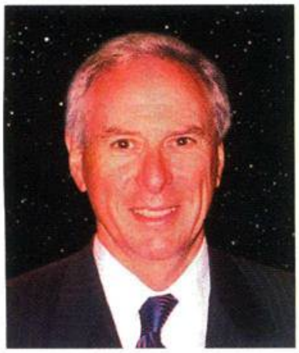
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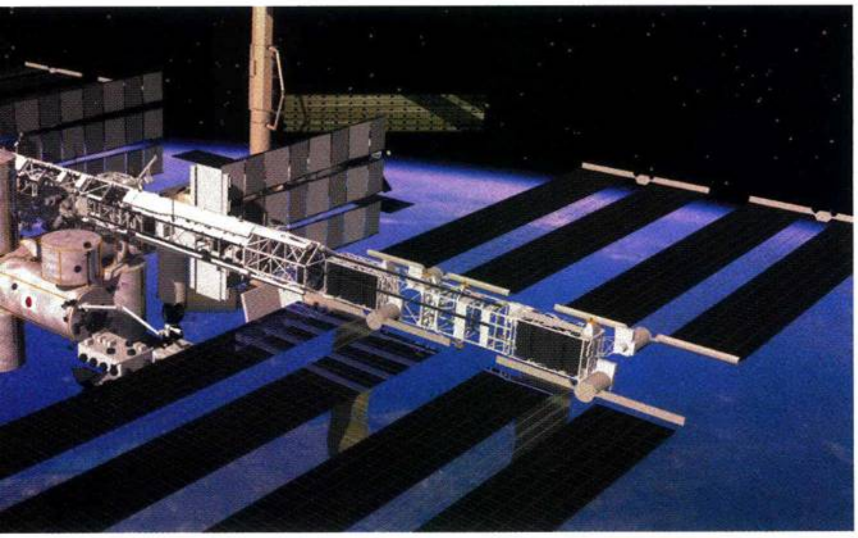

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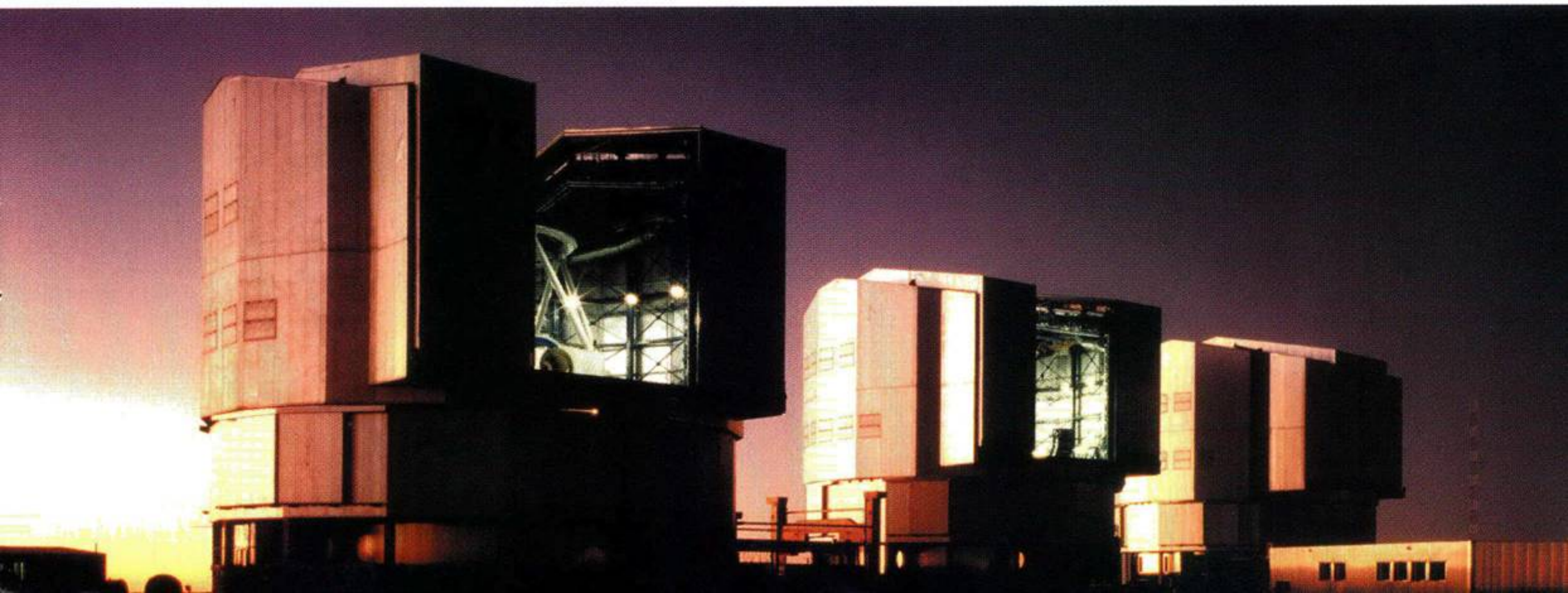

BEHIND THE SCENES

BY BONNIE BILYEU GORDON

Cutting Into Space

We are working our way toward a truly blank slate — not simply a New Year but a New Century. If we were inclined to make resolutions, we could make some doozies this New Year's Eve.

December's New Century issue, which you hold in your hands, offers up our list of predictions and promises for astronomy and space exploration in the 21st century. I suppose it is a list of resolutions, the most hopeful of which would send people flying into space.

After talking to dozens of scientists and administrators, *Astronomy* associate editor Robert Naeye planned and supervised this special issue on the future. He put one writer on the case of human exploration in space. The most definite plans for travel begin with the International Space Station. Although NASA is not officially talking about travel beyond the space station, most people inside and out of the agency think of it as a jumping-off point for planetary exploration. It will prepare travelers for return trips to the moon and for that first tantalizing trip to Mars. Such trips are on the minds of many Americans, stimulated by watching the Sojourner rover creep around Mars and by hearing astronaut Buzz Aldrin promote a tourist trade for the moon. It will shortly be spurred even further by no less than three Hollywood movie projects, the first of which — *Mission to Mars* — will come from Disney in March 2000.

Even if we don't get to go deep into space in the next 100 years, our view of space will be grandly enlarged. Not only will several new telescopes — some with mirrors as large as 100 meters — go to work from the surface of Earth, but NASA plans to send a telescope with gargantuan vision into space.

The real story of what we will find in the 21st century could be reduced substantially as of this writing. The Senate Appropriations Committee has recently recommended a $174-million cut in space science funding. The House too has approved large cuts in space science, putting many projects described in this issue at risk. Congress deals with prosperity in such an odd way. For the first time in decades, we can speak of a budget surplus. The U.S. economy is moving like a fast train, and members of Congress are discussing budget cuts that no one seems to want. Go figure. Or go talk to your Congressperson.

P.S. Due to the completely unexpected and overwhelming response to our contest on renaming brown dwarfs, the judging is not yet complete. We'll report the results as soon as we can.

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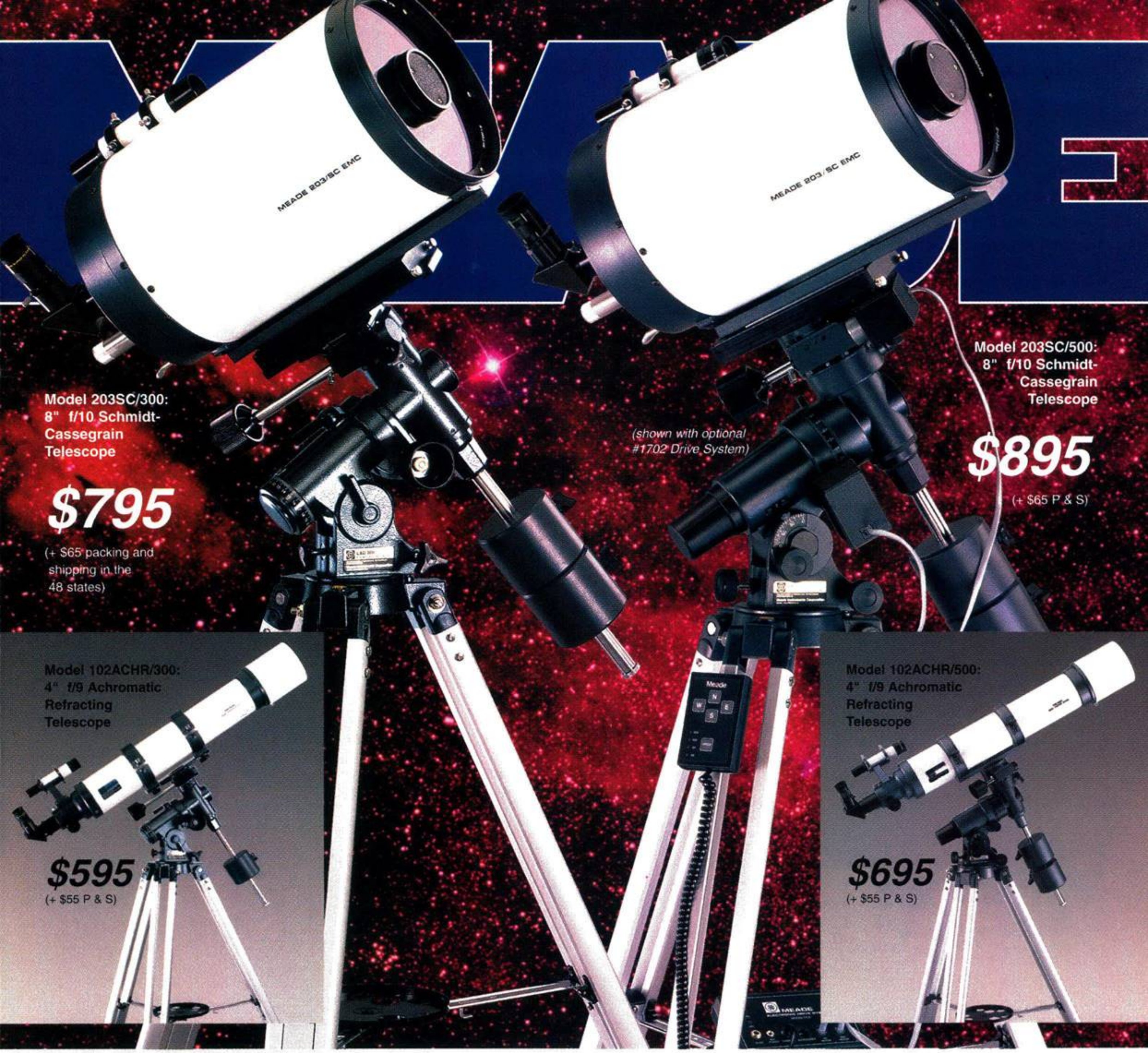
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LXD 300

Now you can buy a Meade® 8" f/10 Schmidt-Cassegrain Telescope, complete with LXD 300 equatorial mount, rigid full-length aluminum tripod, and accessories for only $795! Or a Meade 4" f/9 Achromatic Refractor, complete, for only $595!

Choose either the Meade 203SC/300, with the exact same optical tube assembly as more expensive Meade 8" Schmidt-Cassegrains, or the Model 102ACHR/300 with its exquisite 4" Meade air-spaced achromatic lens. Both telescopes are equipped with the high-performance Meade LXD 300 equatorial mount with dual-axis aluminum worm gears.

SPECIFICATIONS: Models 203SC/300 and 102ACHR/300 — Each telescope includes 8" f/10 Schmidt-Cassegrain *or* 4" f/9 Achromatic Refractor optical tube assembly with EMC super multi-coatings; LXD 300 equatorial mount with aluminum worm gears, micrometric manual slow-motion controls, and setting circles on both axes; manual control for azimuth alignment; elevation control and scale for polar alignment at latitudes from 15° to 50°; adjustable full-length aluminum tripod with bubble level and accessory shelf; 6 x 30mm achromatic viewfinder; eyepiece-holder (1.25"); #918A diagonal prism (1.25"); Series 4000 Super Plössl 26mm eyepiece (203SC) *or* Series 3000 Plössl 25mm eyepiece (102ACHR); provision for addition of optional #812 Polar Alignment Finder; operating instructions. **8" — $795** (+ $65 P & S); **4" — $595** (+ $55 P & S); **#535 R.A. Motor Drive System...$99; #812 Polar Alignment Finder...$49.**

LXD 500

For even broader capability, use the Meade® high-precision LXD 500 equatorial mounting, 20% larger and with dual-axis bronze worm gears — the finest equatorial mounting available in its price class.

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Advanced technology at the most affordable prices *ever.*

■ **Battery-Powered, Completely Cordless Operation!** Meade LX50 models operate for more than 50 hours from six AA-size batteries inserted through the telescope's control panel.

■ **Standard-Equipment Declination Motor and Hand Controller:** Plug the hand controller into the LX50 control panel and you're ready for dual-axis drive capability at any of 4 photo-guide or microslew speeds: 2x, 8x, 16x, or 32x, plus quartz-controlled sidereal-rate tracking in R.A.

■ **Multi-Function Control Panel:** Includes connectors for CCD autoguiders; for the standard-equipment Declination motor; and for the optional Magellan II Computer-Corrector *(below).*

■ **Super Multi-Coated Optics:** The exact same EMC super multi-coated optical tube assemblies included with Meade LX200 models.

■ **Massive LX200-type Fork Mounts:** Manufactured of the same aluminum castings as Meade LX200 models. Massive, rigid mounts that include the Meade LX worm-gear drive system with low periodic error for advanced photographic or CCD imaging applications.

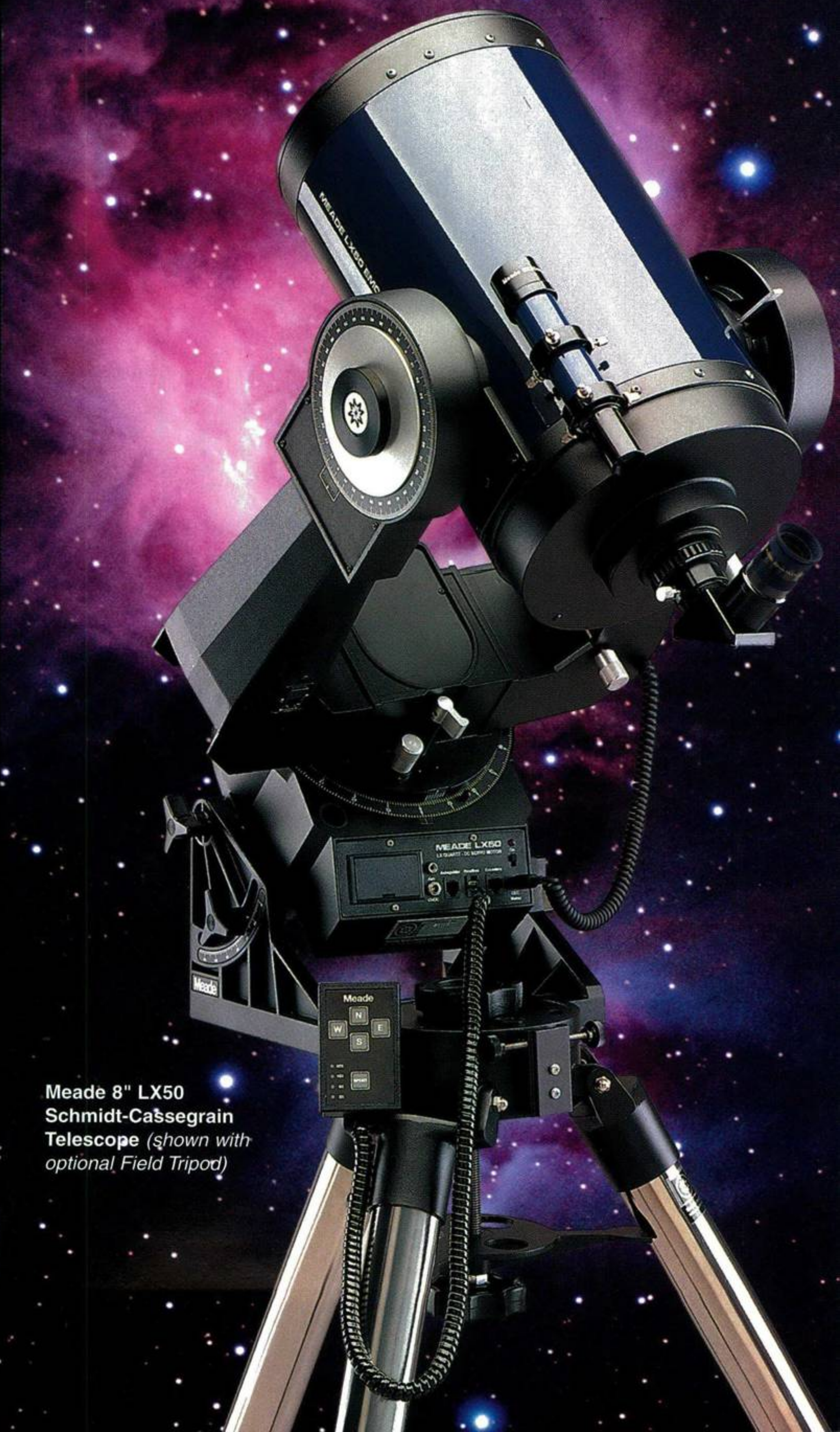
SPECIFICATIONS: 7", 8", and 10" LX50's — Each complete telescope includes 8" or 10" f/10 Schmidt-Cassegrain or 7" f/15 Maksutov-Cassegrain optical tube assembly with EMC super multi-coatings; heavy-duty LX200-type fork mount; 5.75" LX worm gear system in R.A.; multi-function control panel; DC servo Declination motor; manual and electric slow-motion controls on both axes; setting circles on both axes; keypad hand controller; 4-speed drive controls on both axes; battery compartment accepting six (user-supplied) AA-size batteries; 25 ft. power cord for telescope operation from 12v. auto cigarette lighter plug; 6 x 30mm (7" and 8" models) or 8 x 50mm (10") viewfinder; 1.25" diagonal prism; Series 4000 Super Plössl 26mm multi-coated eyepiece (1.25"); standard equatorial wedge with elevation scale, bubble level, and azimuth control; complete operating instructions.

8" LX50 Schmidt-Cassegrain	**$1395.**
10" LX50 Schmidt-Cassegrain	**1695.**
7" LX50 Maksutov-Cassegrain	**1795.**
Variable-Height Field Tripod	**295.**

Packing and shipping in the 48 states: 8"—$105; 10"—$145; 7"—$125; 7" Tube Assembly—$65.

Meade Magellan™ II Computer-Corrector for LX50 Telescopes: Plug the Magellan II into the control panel of your LX50 and enjoy an incredible range of advanced capabilities. ■ Fast manual slewing to any object, either from input RA and Dec or from the 12,218-object database. ■ High-resolution 4096-pulse encoders (5.3 arc-minute precision), concealed in special LX50 encoder compartments. ■ Large 32-character, red-backlighted display. ■ Quick 2-star alignment. ■ Four-speed (2x, 8x, 16x, 32x sidereal) dual-axis drive corrector/microslewing system.

#2024: Magellan II for LX50's—Includes Magellan II hand controller *(shown above)*; encoders for both axes; all required mounting hardware. Installs to any LX50 in minutes. **$495.** + $15 packing and shipping in the 48 states.



Meade 8" LX50 Schmidt-Cassegrain Telescope *(shown with optional Field Tripod)*

MEADE LX200

MEADE LX200 EMC
MEADE LX200
SMART DRIVE
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ENTER
MODE
GO TO

Meade 10" LX200
Schmidt-Cassegrain
Telescope

Prices shown are suggested U.S. national mail-order retail prices.

The largest-selling serious telescopes in the world.

In virtually every country in the world where serious telescopes are sold, more Meade LX200's are sold than all competing models combined. *Standard-equipment includes:*

■ **Superb Optics:** LX200 diffraction-limited imaging capabilities are a legend in the industry; optical performance approaches that of a fine *ED* apochromatic lens.

■ **Automatic GO TO Capability:** Meade LX200's are *the only commercial telescopes ever manufactured* that automatically GO TO any input R.A. and Dec., or to any of 64,359 objects in the onboard database, *to a precision of one arc-minute or better.*

■ **LX200 High-Precision Pointing**™ is so precise it permits the positioning of *every* selected object on *every* commercially-available CCD chip *every* time, automatically — *a feat no other telescope priced under $40,000 can accomplish.*

■ **Permanently-Programmable Smart Drive**™ routinely achieves 5 arc. sec. periodic error, an observatory standard.

■ **9-Speed Dual-Axis Electronics:** Electronics that cover every possible contingency of telescope positioning—from 2x photo-guide, to 32x image centering, to 8°/sec. slewing across the sky, as well as 6 other dual-axis drive speeds in between.

■ **Field Operation:** No other telescopes of such incredible capabilities transport so readily for field operation. The compact, optional #1812 Electronic DC Adapter allows for field powering directly from an automobile cigarette lighter plug.

SPECIFICATIONS: 7", 8", 10", and 12" LX200's — Each complete telescope includes 8" or 10" (f/6.3 or f/10) or 12" f/10 Schmidt-Cassegrain or 7" f/15 Maksutov-Cassegrain optical tube assembly with EMC super multi-coatings; heavy-duty fork mount with 4" polar ball bearing, dual-axis 5.75" worm gears, and multi-function control panel; manual and electric slow-motion controls on both axes; keypad hand controller with digital readout display, permanently programmable Smart Drive, 9-speed drive controls on both axes (7-speed on 12"), High-Precision Pointing, and GO TO controller; 64,359-object onboard celestial software library; 25 ft. power cord and adapter for telescope operation from 115v.AC; 8 x 50mm viewfinder; 1.25" diagonal prism (7", 8", 10") or 2" diagonal mirror with 1.25" adapter (12"); Series 4000 Super Plössl 26mm eyepiece; standard field tripod (7", 8", 10") or giant field tripod (12"); operating instructions.

8" LX200 Schmidt-Cassegrain	**$2795.**
10" LX200 Schmidt-Cassegrain	**3195.**
12" LX200 Schmidt-Cassegrain	**4495.**
7" LX200 Maksutov-Cassegrain	**3295.**

Packing and shipping in the 48 states: 8"—$105; 10"—$145; 12"—$215; 7"—$125.

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MEADE STARFINDER DOBSONIANS

Now with Series 4000 Super Plössl 26mm eyepiece as *standard equipment!* Consider these features:

Series 4000 SP26mm Eyepiece (1.25"): The premium SP26mm ocular permits all Meade Starfinder Dobsonians to perform absolutely to their maximum capabilities. This $80 eyepiece is now **standard-equipment** on all Meade Dobsonians.

Primary and Secondary Mirrors of Low-Expansion Pyrex® Glass: Unlike the plate glass optics of other Dobsonians that can become thermally unstable, all Meade Dobsonian optics are made of Grade-A fine-annealed Pyrex glass — the exact same professional-quality optics used on Meade Starfinder Equatorials.

Rigid, Durable, Beautiful Dobsonian Mountings, manufactured of cabinet-quality materials, provide extremely smooth motions of the telescope in both altitude and azimuth. Both telescope axes ride on zero-backlash Teflon/Nylon bearings, facilitating the quick location and easy tracking of celestial objects.

Full-Size 1.25" Rack-and-Pinion Focuser: For smooth, precise focusing of the image without wobble or backlash. Focus travel is 2.6"; accepts 1.25" eyepieces.

4-Vane Steel Secondary Mirror System: Permits locked-in support and precise centration and alignment of the secondary mirror.

5 x 24mm Viewfinder: Included with all Starfinder Dobsonian models for quick object-location in the main telescope. With crosshair eyepiece and 2-ring bracket.

Optical Tubes: The same strong, spiral-wound Sonotubes™ used on Starfinder Equatorials *(right),* tubes with excellent insulating characteristics that reduce internal thermal currents to an absolute minimum.

Performance! *Meade Starfinder Dobsonians and Equatorials are the largest-selling Newtonian reflectors of their apertures in the world.* Every Starfinder model opens up the skies to an extremely wide range of serious visual observing; all 110 Messier objects, thousands of NGC objects — nebulae, galaxies, star clusters, in all their variations of form, color, and extent, as well as the Moon and planets in stunning high-resolution detail. Starfinder Dobsonians are telescopes for visual observing; motor-driven Starfinder Equatorials may be used, in addition, for lunar and planetary photography, and even for limited deep-space photography.

Packing & UPS Shipping Charges to any address in the 48 states: 6"—$39; 8"—$49; 10"—$69; 12.5"—$79; 16"—$45 packing, shipped truck freight collect.

$270 Dobsonian Deluxe Accessory Package...only $49.95!

Outfit your Meade Dobsonian with all of the most popular accessories for advanced observing. At the time you order any Dobsonian model, specify the following Deluxe Accessory Package for your telescope, in place of the standard-equipment focuser, viewfinder, and eyepiece, ***for a total of only $49.95 additional:***

- 1 - **Meade #77 2" Giant Rack-and-Pinion Focuser,** with machined aluminum eyepiece-holders for both 2" and 1.25" eyepieces; includes drawtube lock and 2.6" focuser travel. *(reg. $59.95)*
- 1 - **Meade #637 6 x 30mm Achromatic Viewfinder,** with wide 7° field; 2-ring metal bracket. *(reg. $49.95)*
- 2 - **Meade Series 4000 Super Plössl 9.7mm and 26mm** multi-coated eyepieces — premium-grade eyepieces for high-resolution lunar, planetary, and deep-space observing. *(reg. $79.95 each)*

Purchased separately, the Deluxe Accessory Package sells for $269.80!

Meade Magellan I Telescope Computer System

Attach the optional Magellan I Telescope Computer System to your Starfinder Dobsonian and finding any of 12,218 celestial objects, or *any* object of known R.A. and Dec., is almost as easy as pointing the telescope! Magellan I's database includes the following objects:

7,840	NGC objects; the complete NGC catalog
4,093	IC objects from the Index Catalog
125	user-defined objects
110	Messier objects; the complete catalog
42	alignment stars for the Magellan system
8	major planets, from Mercury to Pluto
12,218	objects, total

MEADE
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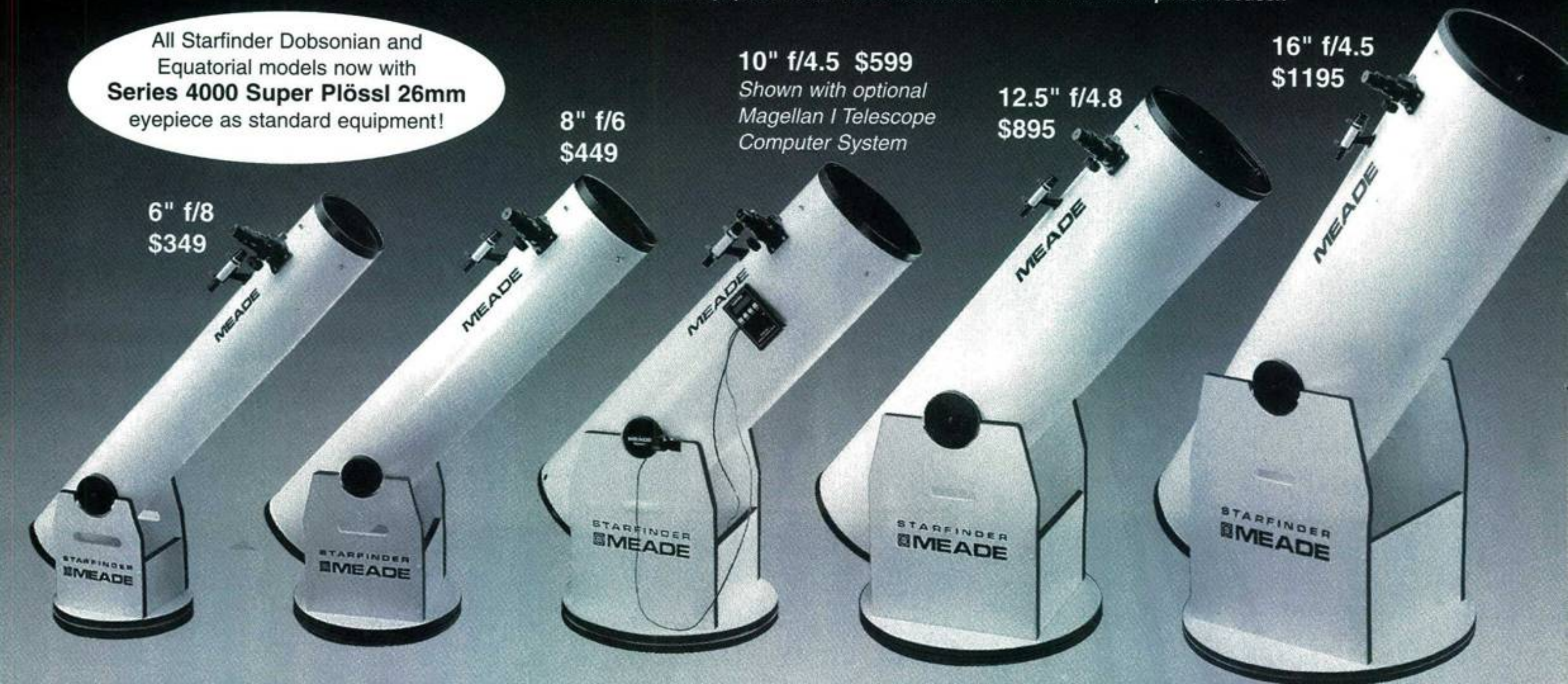
ON
MAGELLAN I
TELESCOPE COMPUTER SYSTEM

Magellan I is supplied *complete* with control/display unit (4" x 5" x 1.25"); premium-grade, high-resolution encoders for each telescope axis (encoder precision is 5.3 arc minutes); RS-232 serial interface; bracket for placement of the controller on the telescope tube; and attachment hardware. Just add the user-supplied 9v. transistor radio battery, and Magellan I is ready to use. First-time installation is quick and simple.

#2010: for Meade Starfinder Dobsonian 6", 8", 10", 12.5", or 16" . . . . $295.
Packing & shipping in the 48 states—$15.

STARFINDER DOBSONIAN TELESCOPES ***Shown with standard-equipment 5 x 24mm viewfinder and 1.25" rack-and-pinion focuser.***



All Starfinder Dobsonian and Equatorial models now with **Series 4000 Super Plössl 26mm** eyepiece as standard equipment!

6" f/8 $349

8" f/6 $449

10" f/4.5 $599
Shown with optional Magellan I Telescope Computer System

12.5" f/4.8 $895

16" f/4.5 $1195

MEADE
STARFINDER EQUATORIALS

With DC-powered drive systems for automatic tracking and Series 4000 Super Plössl 26mm eyepiece.

Professional-Grade Optical System: Hand-figured, parabolic primary mirror and elliptical flat secondary, both of Grade-A Pyrex glass. Optics are multi-coated and meet the theoretical limits of resolution.

Accessories and Components: Premium-grade multi-coated SP26mm eyepiece (1.25"); #637 6 x 30mm viewfinder with wide 7° field; strong, durable, spiral-wound optical tube with attractive white finish.

Precision Equatorial Mount: Manufactured of machined aluminum to tolerances of .001" or better, with 4"-dia. pier and die-cast tripod legs for rock-solid support of the optical tube. Moves effortlessly from object to object on precision bearing surfaces. Polar and Dec. shafts are 1" solid steel. Setting circles on both axes.

Battery-Powered Cordless Drive System! For fully automatic tracking of celestial objects. Operates over 50 hours from 6 (user-supplied) AA-batteries. Control panel also permits powering the telescope from 12v. auto cigarette lighter plug, using optional 25 ft. cord.

2" Giant Focuser: Meade #77 2" giant rack-and-pinion focuser is included as standard equipment, with eyepiece-holders for both 2" and 1.25" eyepieces.

Starfinder Equatorial 16: Includes equatorial mounting with 1.5" steel shafts, Sealmaster ball bearings, 6" dia. pier, and 6 x AA-size battery-powered worm gear drive; 8 x 50mm viewfinder; #77 2" giant focuser.

Packing & UPS Shipping Charges to any address in the 48 states: 6"—$65; 8"—$75; 10"—$90; 16"—$55 packing, shipped truck freight collect.

Meade Magellan Telescope Computer Systems

MEADE
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MAGELLAN I
TELESCOPE COMPUTER SYSTEM

Magellan I: Use the Magellan I computer to manually slew the telescope quickly to any of 12,218 database objects, or to any object of known R.A. and Dec. Specifications and object database are identical to Magellan I for Starfinder Dobsonians *(see facing page)*.

#2011: for Meade (DC-powered) Starfinder Equatorial 6", 8", or 10" . . . . $295.
#2012: for Meade (DC-powered) Starfinder Equatorial 16" . . . . 295.

MEADE
MAGELLAN II
COMPUTER CORRECTOR
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Magellan II Computer-Corrector: Plug the Magellan II into the control panel of your Meade Starfinder Equatorial and you have all the capabilities of the Magellan I, above, including 12,218-object database, *plus* a 4-speed (2x, 8x, 16x, 32x), dual-axis, drive corrector/microslewing system.

#2018: for (DC-powered) Starfinder Equatorial 6", 8", 10" . . 495.
#2019: for (DC-powered) Starfinder Equatorial 16" . . . . 595.

Packing & shipping in the 48 states: Magellan I–$15, Magellan II–$20.

Special Eyepiece Offer! At the time you order any Meade Starfinder Equatorial telescope, you can buy a Meade Series 4000 Super Plössl 9.7mm eyepiece ***for only $29.95!*** *Purchased separately, the SP9.7mm eyepiece sells for $79.95.*

New 120-page 1999-2000 Meade General Catalog!

Write, call, or fax Meade Instruments for your free copy.

To Order: Contact your authorized Meade Advanced Products Mail-Order Dealer, below. Prices shown are suggested U.S.A. mail-order retail prices.

ASTRONOMICS, Norman, OK.
Orders: 800-422-7876; Info.: 405-364-0858.

FOCUS CAMERA, Brooklyn, NY.
Orders: 800-221-0828; Info.: 718-436-6262.

LUMICON, Livermore, CA.
Orders: 800-767-9576; Info.: 925-447-9570.

OCEANSIDE PHOTO & TELESCOPE, Oceanside, CA.
Orders & Information: 800-483-6287.

POCONO MOUNTAIN OPTICS, Moscow, PA.
Orders: 800-569-4323; Info.: 570-842-1500.

RIVERS CAMERA, Dover, NH.
Orders: 800-245-7963; Info.: 603-742-4888.

SHUTAN CAMERA & VIDEO, Chicago, IL.
Orders & Info.: 800-621-2248; IL: 312-332-2000.

Canada:

EFSTONSCIENCE, Toronto, Ontario.
Orders & Information: 416-787-4581.

KHAN SCOPE CENTRE, Toronto, Ontario.
Orders & Information: 416-783-4140.

ADVANCED PRODUCTS DIVISION
Meade Instruments Corporation
The largest-selling telescopes in the world. ☐ A NASDAQ company.
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FAX: (949) 451-1460 ☐ *www.meade.com*
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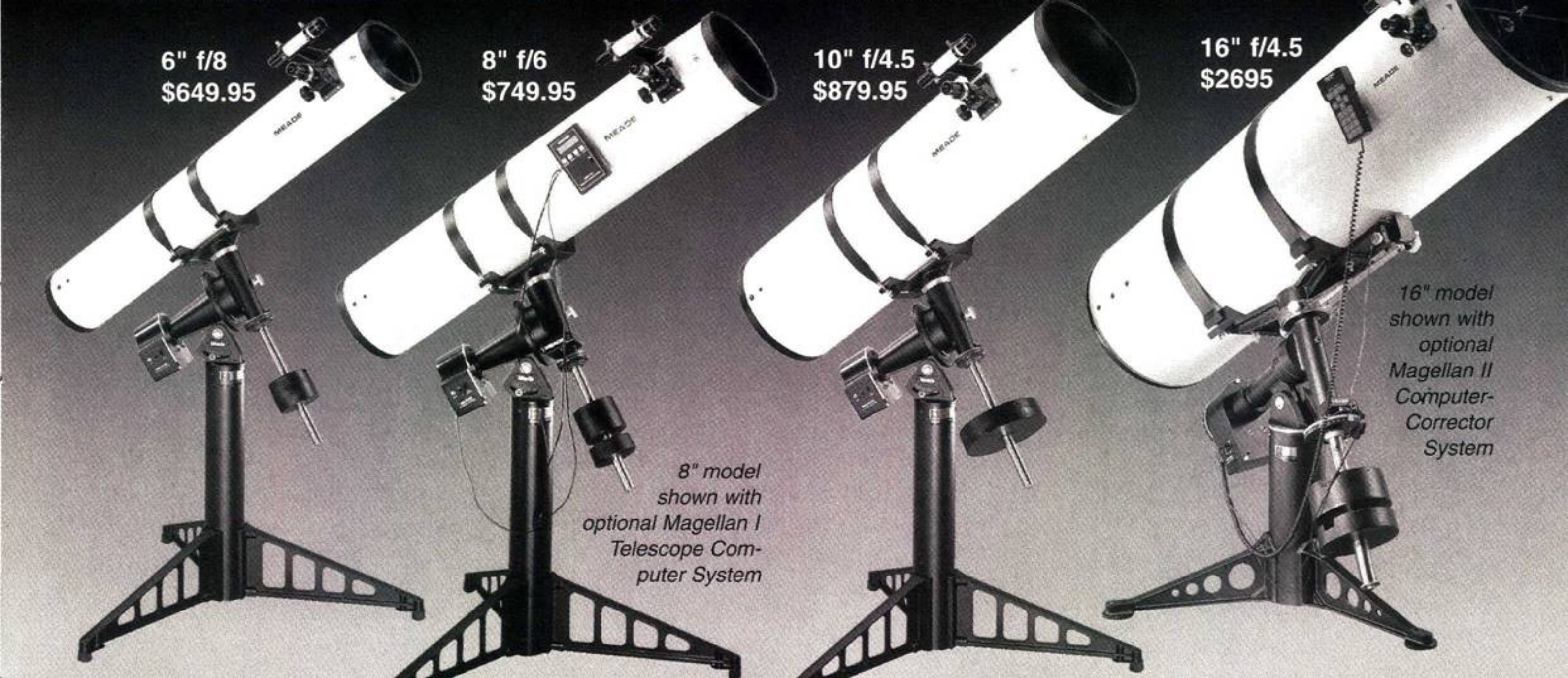
STARFINDER EQUATORIAL TELESCOPES ***Shown with standard-equipment 6 x 30mm or 8 x 50mm viewfinder and 2" giant focuser.***



6" f/8
$649.95

8" f/6
$749.95

8" model shown with optional Magellan I Telescope Computer System

10" f/4.5
$879.95

16" f/4.5
$2695

16" model shown with optional Magellan II Computer-Corrector System

RESEARCH-GRADE ACCESSORIES

Series 4000™ Super Plössls
52° field; multi-coated

Meade 4-element Super Plössls, updated and redesigned to utilize the latest in optical glass-types, are the finest general-purpose eyepieces available. For observing hairline lunar and planetary detail, splitting close doubles, or for deep-space; guaranteed to deliver more contrast and image sharpness than any other brand. Rubber eyeguards fold down for eyeglass wearers–a feature not available on competing brands. Multi-coated. All focal lengths through 32mm are parfocal.

Super Plössls (SP; 4-elements; 1.25"; 52°):

6.4, 9.7, 12.4, 15, 20, 26mm	each:	**$79.95** (4.54)
32mm (52°); **40mm** (44°)	each:	**99.95** (5.26)
56mm (52°; 2")		**199.95** (7.02)

Series 4000™
2x Apochromatic Barlow Lens

#140: The most advanced Barlow lens available for commercial telescopes, the Meade #140 includes 3-element, multi-coated, air-spaced optics. Doubles the power of any eyepiece with which it is used and yields images absolutely unmatched in resolution, contrast and color correction. The #140 optically complements any telescope — refractor, reflector, or Schmidt-Cassegrain. Accepts 1.25" eyepieces. Mechanical components are of machined aluminum and brass. Lens diameter is 28mm; clear aperture 26mm.

$79.95 (5.26)

Series 4000™
Super Wide Angle
67° field; multi-coated

For exquisite wide-angle images at low-to-medium powers, with pinpoint edge-of-field resolution. Ideal for star fields, galaxies, and other deep-space phenomena. SWA 13.8mm, 18mm, and 24.5mm are superb complements to the #140 Barlow, above.

Super Wide Angle (SWA; 6-elements; 1.25"; 67°)–**13.8mm: $139.95** (4.54); **18mm: 149.95** (4.54); **24.5mm: 179.95** (5.26); **32mm** (2"): **239.95** (7.02); **40mm** (2"): **299.95** (7.02)

Series 4000™
Ultra Wide Angle
84° field;
multi-coated

The ultimate eyepieces; extreme image sharpness over an amazing 84° field. A perfect optical match with Schmidt-Cassegrains and fast Newtonians.

Ultra Wide Angle (UWA; 8-elements; 1.25"; 84°)– **4.7mm: $169.95** (5.26); **6.7mm: 199.95** (5.26); **8.8mm** (1.25"/2"): **239.95** (7.02); **14mm** (1.25"/2"): **299.95** (7.02)

World's Most Advanced Illuminated Reticle Eyepiece

Series 4000 Plössl 9mm, with rubber eyecup and micrometric X-Y positioning of the reticle within the field. Greatly facilitates locking on the guide star. Sharp high-power imaging, excellent eye relief. Wireless red LED illuminator with adjustable brightness control. Multi-coated optics. **Internal batteries included.** Bullseye reticle. 1.25".

$149.95 (6.14)

Series 4000 Plössl 9mm—Same as above but with 6 ft. cord and plug for Meade LX3, LX5, LX6, LX100, LX200, and APO power panels, in place of wireless illuminator.

$129.95 (5.26)

Series 3000™ Plössls
50° field; multi-coated

Meade Series 3000 Plössls yield the finest image corrections obtainable from the classical 4-element Plössl design. Focal lengths from 5mm through 25mm are parfocal, so that, at most, only slight refocusing of the image is necessary from eyepiece to eyepiece. Unlike competing moderately-priced Plössls, Meade Series 3000's are **multi-coated** for maximum light transmission and image contrast. Chrome-plated brass barrels are threaded for standard filters. All eyepieces are fitted with fold-down rubber eyecups for comfortable observing. The PL40mm *(far right in photo)*, an excellent complement to any ocular set, produces spectacular low-power, wide fields, ideal for scanning the Milky Way. Manufactured exclusively to Meade optical designs, Series 3000 Plössls yield fine, high-resolution results on reflectors, refractors, and Schmidt-Cassegrains of any focal ratio.

Series 3000 Plössls (4-elements; 1.25"; 50°)
5, 6.7, 9.5, 16, 25mm each: **$49.95** (3.86); **40mm** (44° field): **$79.95** (3.86)

Series 4000™
f/6.3 Focal Reducer/ Field Flattener

f/6.3 FOCAL REDUCER/FIELD

Manufactured to exclusive Meade optical designs; threads on to any Meade or Celestron Schmidt-Cassegrain rear cell and converts f/10 scopes to f/6.3 (or f/6.3 SCT's to f/4), while significantly flattening the field. Use with SCT visual or photo accessories. Actual visual field is increased by 56%, for fine wide-field views of star fields and nebulae. In astrophotography, reduces exposure times by about 50%, while producing an actual field diameter of 1.5" at the film plane. A tremendous aid with CCD imagers in reducing image size for locating and centering images on CCD chips. 4-element optics; multi-coated; 41mm clear aperture. **$129.95** (5.26)

Series 4000 Photo-Visual Color Filters (1.25")–Premium filters, made of purest crown optical glass, dyed in the mass. For increased contrast and resolution on the Moon and planets. Thread into the barrels of virtually all 1.25" eyepieces sold today. Fully coated.

#8 Lt. Yellow; #11 Yellow Green; #12 Yellow; #21 Orange; #23A Lt. Red; #25A Red; #38A Dark Blue; #47 Violet; #56 Lt. Green; #58 Green; #80A Blue; #82A Lt. Blue

each **$14.95** (2.73)

Set #1–4 filters: #12, #23A, #58, #80A	**49.95** (4.54)
Set #2–4 filters: #11, #25A, #47, #82A	**49.95** (4.54)
Set #3–4 filters: #8, #21, #38A, #56	**49.95** (4.54)

Series 4000 Moon Filter (#ND96): Reduces glare and irradiation during lunar observing. 13% uniform light transmission across the visual spectrum. Threads into 1.25" barrels. **$16.95** (2.73)

#911B
#910B
#908B
#911N
#910N
#908N

Series 4000 Nebular Filters—Premium multi-layer interference filters, the finest obtainable. Use broadband ("B") filters to block most forms of light pollution; use narrowband ("N") filters in heavily light-polluted areas or for extremely high-contrast observing of faint nebulae.

#908B–Threads into 1.25" eyepieces, 26mm dia.	**79.95** (4.54)
#910B–Threads into 2" eyepieces, 44mm dia.	**119.95** (5.26)
#911B–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia.	**99.95** (5.26)
#908N–Threads into 1.25" eyepieces, 26mm dia.	**89.95** (4.54)
#910N–Threads into 2" eyepieces, 44mm dia.	**129.95** (5.26)
#911N–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia.	**119.95** (5.26)

#911X
#910X
#908X

Series 4000 Oxygen-III Filters Observe diffuse emission and planetary nebulae as you never thought possible! Exclusive Meade *60-layer* interference coating technology isolates the 496nm and 501nm O-III lines to tremendously enhance observable nebular structural detail in all telescopes.

#908X–Threads into 1.25" eyepieces, 26mm dia.	**99.95** (4.54)
#910X–Threads into 2" eyepieces, 44mm dia.	**159.95** (5.26)
#911X–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia.	**149.95** (5.26)

2x Telenegative Barlow (1.25")

#122: Doubles eyepiece power with sharp, high-resolution, high-contrast imaging on telescopes of all types. 27mm dia. (26mm clear aperture). Excellent corrections for chromatic and spherical aberrations at all photo-visual wavelengths. Multi-coated. 1.25"

$47.95 (4.54)

#905 Variable Polarizer (1.25")

For glare reduction in observing the Moon. Includes two Polarizer filters mounted in a machined cell and permits continuously variable light transmission from 5% to 25%, to compensate for varying lunar surface brightness according to the Moon's phase and the aperture of the telescope. Accepts 1.25" eyepieces. **$49.95** (5.26)

2x Short-Focus Barlow (1.25")

#126: Only 2.5" long, the #126 works well with any telescope accepting 1.25" eyepieces, even those with limited focus range. Maintains the high image quality of the #122, above. Insert the #126 into star diagonal for 2x or insert star diagonal into #126 for 3x. 26mm clear aperture. Multi-coated. **$47.95** (4.54)

2x-3x Variable Barlow (1.25")

#127: Precision internal sliding lens assembly permits continuously variable power settings between 2x and 3x. Engraved scale indicates power in use. Yields bright, sharp, high-contrast images on telescopes of all types. Multi-coated; 1.25".

$59.95 (4.54)

Electric Focusers for SCT's

For extremely smooth microfocusing of the image. Does not affect use of the manual coarse-focus knob.

#1206 Electric Focuser: Plugs into control panel of Meade 8", 10", 12" LX200 models and operates from LX200 hand controller. **$149.95** (7.48)

#1205 Electric Focuser: For all other Meade 8", 10", 12" SCT models; includes separate hand controller; accepts one self-contained (user-supplied) 9v. battery.

$169.95 (7.88)

Modified Achromatic Eyepieces

Meade 3-element MA eyepieces yield sharp, well-corrected images on the Moon, planets, and deep-space at a reasonable price. Multi-coated; threaded for filters; 1.25" barrel diameter. Apparent field: 40°. **MA 9, 12, 25, 40mm.**

each: **$37.95** (4.54)

MA12mm Illuminated Reticle Eyepiece

Excellent 3-element optical system, long eye relief, fully coated, with double crossline reticle; rubber eyecup. Wireless red LED illuminator and variable brightness control. 1.25". **Batteries included.**

$99.95 (3.45)

As above but with 6 ft. cord and plug for Meade telescopes with power panels, in place of wireless illuminator. **$79.95** (5.26)

Camera Adapters

Professional-quality adapters for rigid coupling of telescope-to-camera. Use for either Eyepiece-Projection or Prime Focus. Precision-machined of aluminum and brass, threaded for filters. Use with T-mount, available separately.

.965": $27.95; **1.25": $29.95** (3.86)

Variable-Projection Camera Adapter (1.25")

Machined sliding cell allows variable projection power in eyepiece-projection photography; permits precise selection of correct photo power in lunar and planetary photography; threaded for filters. Use with T-mount for your camera.

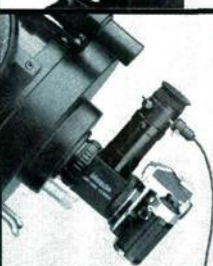
$39.95 (3.86)

2" *Diagonal* Mirror

#929: Permits use of wide-field 2" oculars. Threads on to rear cell of Meade and Celestron SCT's. Includes multi-coated precision optical flat made at the Meade factory; with 1.25" eyepiece adapter. **#930:** Same as #929 but with 2" barrel to fit into focusers with 2" eyepiece-holders.

#929 or **#930,** each: **$99.95** (6.85)

#777 Off-Axis Guider for SCT's



Internal prism diverts light for monitoring telescopic image during long-exposure astrophotography. Threads to any Meade or Celestron rear cell. Use with illuminated reticle eyepiece and T-Mount for your 35mm camera.

$79.95 (6.85)

Variable Tele-Extender

For eyepiece-projection photography with any Meade or Celestron SCT. Threads on to eyepiece-holder. Sliding cell with lock permits wide range of projection magnifications with the same eyepiece. Use with T-mount for your camera.

$39.95 (3.86)

45° Erecting Prisms

Fully coated roof prisms to invert the astronomical image in Schmidt-Cassegrains or refractors during terrestrial observations, while presenting a convenient 45° observing angle. Specify **#927** (.965"), **#928** (1.25"), or **#931** (fits .965" focuser, accepts 1.25" eyepieces).

$42.95 (3.86)

T-Adapters for SCT's

Rigidly couples camera to telescope for prime focus photography with any Meade or Celestron Schmidt-Cassegrain. Use with T-Mount for your 35mm camera.

$26.95 (3.86)

CCD-Photo-Visual Flip-Mirror Systems

An essential accessory for imaging with ***any*** brand of CCD imager or for astrophotography with a 35mm camera. Flip mirror "down" to center the image while viewing with an eyepiece at 90°; flip mirror "up" to pass light on to CCD chip or 35mm camera film plane. Each unit includes: precision optical-flat Pyrex® mirror; 2-axis mirror-adjustment screws and locks for precise image centering; extra-fine helicoid focusing of the eyepiece; extension tubes for attaching either 35mm camera (using T-Mount) or CCD imager (using either T-threads or 1.25" barrel). Threads to rear cells of all Schmidt-Cassegrain telescopes; may remain on telescope and used in place of diagonal prism for visual observing as well.

"Over the past 10 years I have used all manner of flip-mirrors. The Meade Flip-Mirror Systems are absolutely the best—rock solid, high-precision, beautifully manufactured; they virtually eliminate all flexture between the CCD and telescope." — Jack Newton

#644 Flip-Mirror System: Accepts any 1.25" eyepiece. Mirror clear aperture: 22mm. Use with CCD's up to Pictor 416XT or ST-7, or smaller; or visual observing with 1.25" eyepieces. **$149.95** (7.02)

#647 Flip-Mirror System: Accepts either 1.25" or 2" eyepieces. Mirror clear aperture: 40mm. Recommended for full-field 35mm astrophotography or with CCD's of any size, including all Meade Pictor Series through 1616XT, as well as ST-4 through ST-8; or for visual applications with 1.25" or 2" eyepieces. **249.95** (8.49)

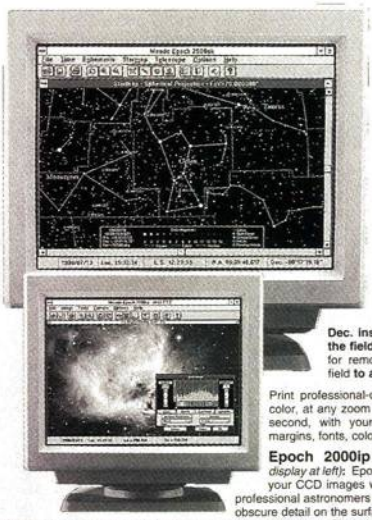
#157 1.25" Adapter: Permits use of either Flip-Mirror on telescopes with 1.25" eyepiece-holders. (Requires approx. 2" additional focus travel with #644, 3" with #647.) **15.00** (3.86)

#644

MEADE
FLIP-MIRROR SYSTEM

#647

MEADE
FLIP-MIRROR SYSTEM



Epoch 2000® Sky Software

The most powerful astronomical software ever made available can now be yours for only $149!

Epoch 2000sk *(upper display at left):* Now you can use the most advanced, most precise full-color sky software ever created, to zoom-in on telescopic fields **smaller than one arc second!** With star positions displayed as precisely as **0.01 arc second,** the Trapezium in Orion is no longer shown as a single point, as in other software, **but as four precisely oriented starpoints, just as they appear in the telescope.** No longer do you need to guess the R.A. and Dec. of an object located away from the field center, as in other programs: Epoch 2000sk dynamically reads out the R.A. and Dec. of the cursor position anywhere in the field **and updates R.A. and Dec. instantaneously as the cursor is moved about the field.** Meade LX200 owners can use Epoch 2000sk for remote auto-centering of objects in the telescopic field **to a precision of 30 arc seconds,** routinely!

Print professional-quality star charts in either black-and-white or color, at any zoom setting or sky scale between 180° and one arc second, with your own customized borders, headers, footers, margins, fonts, colors, and grids.

Epoch 2000ip Image Processing Software *(lower display at left)*: Epoch 2000ip makes it easy to enhance and analyze your CCD images with the same sophisticated techniques used by professional astronomers to uncover hidden structure in a spiral galaxy or obscure detail on the surface of a planet. This powerful software includes virtually every technique available for image enhancement. Techniques that bring out detail totally invisible in your original image, transforming it from the ordinary to the spectacular.

EPOCH 2000sk Sky Software: 281,000 objects supplied on 3.5" discs for Windows 3.1 or higher; fully compatible with Windows 95 .... **$149**

EPOCH 2000sk-CD Sky Software: 19 million objects, including the complete Hubble Guide Star Catalog; supplied on CD-ROM **179**

LX200 Interface Cable: for Meade LX200 operation by Epoch 2000sk **25**

EPOCH 2000ip Image Processing Software: Supplied on 3.5" discs for Windows 3.1 or higher; fully compatible with Windows 95 .... **$199**

f/3.3 CCD FOCAL REDUCER

Series 4000™ f/3.3 CCD Focal Reducer/Field Flattener

NEW!

Revolutionary 3-element Meade design permits ultrafast CCD imaging with **increased** edge-of-field resolution and color correction! Reduces CCD exposure times by up to 80%. Threads on to the rear cell of any Meade or Celestron Schmidt-Cassegrain. Converts f/10 Schmidt-Cassegrain telescopes to **f/3.3** and f/6.3 SCT's to **f/2.** Variable T-Adapter (included) allows range of f/ratios between f/3 and f/5 on f/10 SCT's and between f/1.9 and f/3.2 on f/6.3 SCT's. Use with CCD imagers of any brand and chip dimensions. Not for visual or photographic applications. Multi-coated; 41mm clear aperture. **$149.95** (5.26)

Plössl 25mm Illuminated Reticle CCD Framing Ocular

NEW!
MEADE
PLÖSSL
CCD FRAMING

Displays rectangular frames of all popular CCD chip sizes, including all Meade Pictor models and ST-4 through ST-8. Shows precisely the image size and orientation that appear on CCD chip. Insert directly into telescope eyepiece-holder, or use with Flip-Mirror *(above).* Includes 4-element coated Plössl optics; lockable spacer ring to fix focus position; rubber eyecup; variable LED illumination control; batteries. 1.25".

$129.95 (4.54)

#825 8 x 25mm Right-Angle Viewfinder for ETX-90

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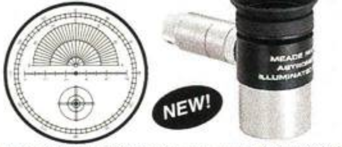

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Sorting the Planets from the Stars

The news story "A Planet That's Probably Not" (October 1999) stated that the scientists took a spectrum of TMR-1C to find out if it was a planet or a star. The conclusion was that it might be too hot for a planet. Why can't scientists use the spectrum to determine the chemical composition of the object and determine if it is made out of the gases of a star? — *Dan Bowling, Coon Rapids, Minnesota*

Jupiter and the sun have basically identical elemental compositions; both are predominantly made up of hydrogen and helium with a few percent heavier elements. Because Jupiter is much cooler than the sun, the elements in its atmosphere combine to form molecules. Spectra of Jupiter and the sun are very different. The same will be true for planets that we will find outside the solar system — their compositions will be essentially the same as that of the surrounding stars. By observing the spectrum, the first thing we will learn is the temperature of the object. Because the temperatures of the coolest stars (about 2000 K) are similar to the temperatures of very young, massive planets, these objects will have almost identical spectra. For example, the coolest stars and the hottest planets will have abundant water vapor in their atmospheres that will be detectable in their spectra.

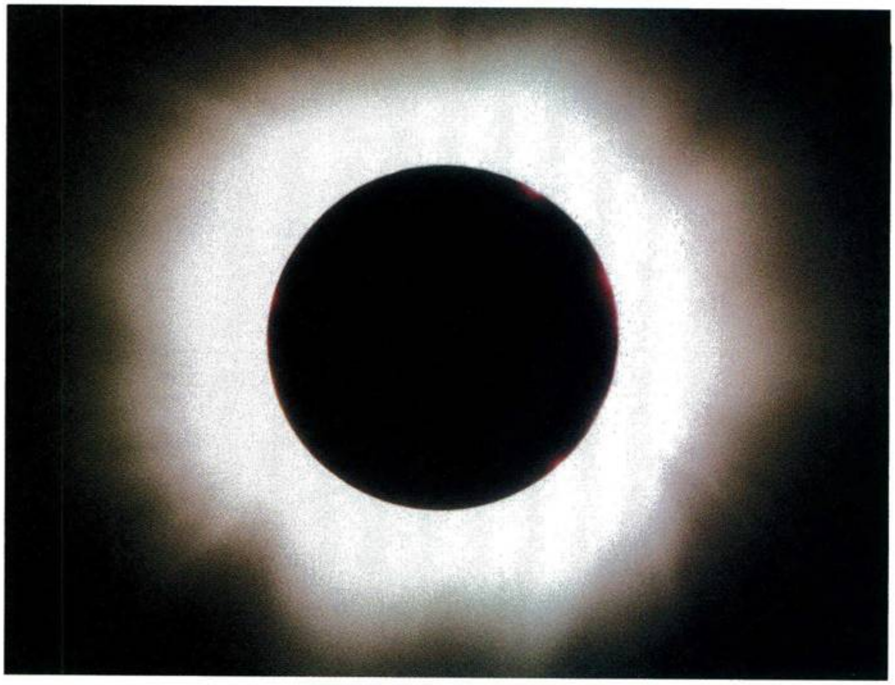
The spectrum of TMR-1C does not show evidence for water vapor, and other spectral features indicate a temperature of about 3000 K, too hot for even a young super-Jupiter. — Ken Noll, Space Telescope Science Institute, Baltimore, Maryland

Skyspeak

I was amazed and amused reading the article "The Art of Skyspeak" in the September issue. Amazed because it brings up an issue to which most romance-language speakers never pay attention. For those who speak Spanish or Italian, as I do, it's easier to pronounce constellation and star names correctly, because Latin is the mother tongue of both languages, and Spanish acquired a huge number of Arabic terms during the eight centuries Arabs dominated the Iberian Peninsula.

I was amused because English-speaking people have to create a funny letter game to illustrate sounds. We have five vowels, as most languages do, pronounced as follows: "A" as in cat, "E" as in egg, "I" as in big, "O" as in box, and "U" as in moon. So, Spica (Latin word for "ear of wheat") is pronounced "SPEE-kah." In Arabic star names such as Aldebaran, Alnilam, and Alkaid, "Al" replaces the English article "the." These names should be pronounced with two stressed syllables. "Al" needs to be stressed, but there is always another stressed syllable in the given name: Al-debarán, Al-nilám, Al-kaíd, Al-gól, Al-cór, Al-résha, etc.

One of my major interests in astronomy is researching star names of either Latin or Arabic origin. I hope these rules about vowel pronunciation will help your readers to Skyspeak correctly. — *Patrizia Grassi, Caracas, Venezuela*



A round and even corona was the signature of the August 11, 1999, eclipse. Dave Buchla

Television's Eclipse

Since I couldn't make it to Europe for the total solar eclipse, I dragged myself out of bed at 3 A.M. to experience a vicarious thrill via live coverage on the Discovery Channel. Given their record of excellent programs about other astronomical topics, I'd been looking forward to this show for days.

I was a little groggy throughout my whole 75 minutes of viewing, after which I promptly went back to sleep. When I awoke, I couldn't decide if I had actually seen these highlights of their coverage or dreamt them. All I remember is that it didn't seem like I saw more than fleeting glimpses of totality during those 75 minutes.

Did any of this really happen? A panel discussion cut away to an image from a typically cloudy region in Eng-

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land to a perfectly focused image of the sun, 85 percent covered. The panel expert said totality must be only seconds away. After ten minutes of discussion in the studio, the 95-percent-covered sun was well out of focus. The Brits at the scene cheered during a brief moment when totality was visible, and television viewers were treated to a second of out-of-focus corona. Well after third contact, the photographer discovered infinity again.

Then there was an interview — during totality — with a woman who viewed a previous eclipse at age 15 in England in 1927. They came back from this segment to mention that she's 89 years old. Had I slept all the way into the next millennium?

Also while the shadow was sweeping across Europe, a lengthy interview in the studio ensued about memorabilia that may be worth something one day. Never mind the corona; here was a chance to capitalize on the eclipse. Among other items of worth was a partially "eclipsed" ceramic plate.

Next up was a decent segment on the 1991 event in Baja. It wasn't bad, but it wasn't live, either. Then a live feed of totality from Romania with a very short focal length optic was terminated abruptly just as the diamond ring of third contact began. Their phones must have been ringing off the hook with angry viewers deprived of panel discussion.

I must have been really sleepy, because I could swear that they ran a pre-recorded segment about English witches while the shadow moved into clear skies in Eastern Europe. They came back to the studio to interview a witch and a witch doctor. The interview was interrupted in favor of a another feed from Romania. The moderator commented on the beauty of the scene, which was due to diffraction spikes emanating from the aperture stop of an extremely short lens.

Next, Discovery's coverage moved back to England to interview three 12-year-olds about their thoughts on the cloudy eclipse.

More than an hour into the program, viewers were treated to the first clear, properly exposed view of totality. But again, perhaps I'd dozed off and was dreaming about a past experience. A space exploration expert who hadn't ever actually seen a total solar eclipse was up next in the studio. The moderator read a question from a viewer asking why the corona sometimes appears pointed and other times appears to be round. The expert said that he was not an expert on photography or the nature of the corona.

I'm sure I was sound asleep and twitching as I dreamt that they interviewed an astrologer about the significance of actually being born at the moment of totality.

I awoke in a haze that morning, wondering what had happened. After initially being upset with Discovery Channel of Europe, I saw it as a consolation that British television can indeed be as insipid as American television, if it tries hard enough. — *Tom Polakis, Tempe, Arizona*

Except in Hungary and Romania, Europe's weather was unreliable on August 11 and very little television coverage was possible from easily accessible locations. It does seem that a channel that promised a live worldwide broadcast would factor in for contingencies (beyond questioning 12-year-olds).

Though Americans often attribute superior intellectual traits to the British, even those old-world citizens make mistakes. British newspapers reported that an official with the National Health Office of the United Kingdom warned that people should stay inside during the eclipse and watch it on television so they wouldn't hurt their eyes. — Astronomy editors

The Big Peas

Your article "Give Peas a Chance" poses the questions: But where did all the matter and energy in the universe come from? And what really put the BANG in the Big Bang?

From a cosmological standpoint, the more important questions are where did all the information in the universe come from? And what put the LAW in Natural Law?

Turok claims, "One can predict everything about the universe from this initial instanton. . . . The calculations are very precise." Do the calculations predict the "evolution" of the information necessary for the clotting mechanism? Where did the mathematical structure, upon which those precise calculations hang, come from? What is the nature of the underlying mathematical structure, or as the Greeks called it, the Logos? It appears that it turns out, as the Apostle John said, that "In the beginning was the Logos." [John 1:1] — *Nancy Odom, Crescent City, California*

Astronomy on the Cheap

Bob Berman's story in the October issue was a wonderful reminder: Knowing the subject of our fascinations is more important than being fascinated by gadgets.

Don't get me wrong. I'm just as guilty as most of you. I have far too many observing toys But, when I realized that I had a different telescope for each day of the week, well . . . enough was too much.

I have had the time more recently to learn astronomy the right way. I made a decision I'd like to add to Bob Berman's suggestions. I took a couple of astronomy classes at a local college. A theoretical and an observational astronomy lab class gave me the exposure, knowledge, and skill to reclaim my earliest fascination with the night sky. I hope it will also keep me from getting frustrated and losing interest with my gadgets. This was the best $38 in fees (on each class) I've spent toward my favorite hobby. I had access to all kinds of nice scopes and learned how to use them, and that helped me to decide what to buy when I was ready. Studying what goes on in the cosmos will also help keep me interested and excited. — *Keith Benicek, Southern California*

Correction

Martin Ratcliffe's name was inadvertently omitted as author of "Astronomy's 2000 Guide to the Sky" in the table of contents of our annual, *Explore the Universe.* Instead the story was attributed to its editor. Our apologies. — *Astronomy* editors

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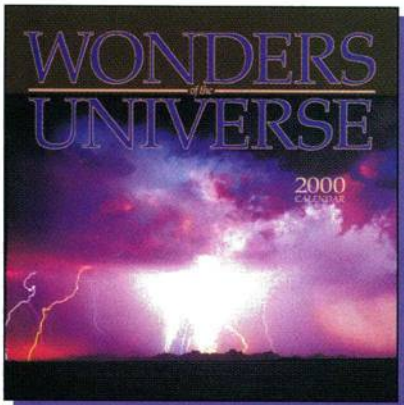

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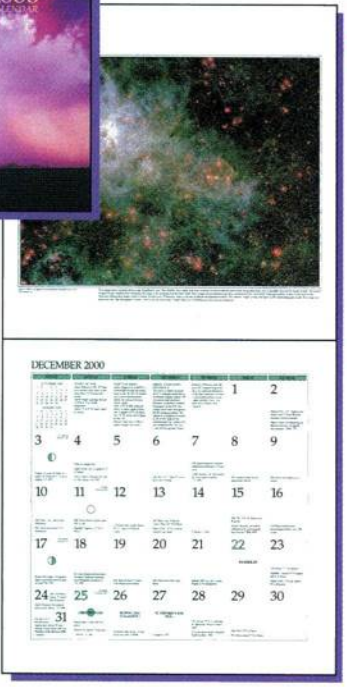

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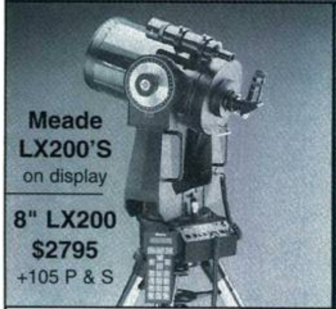

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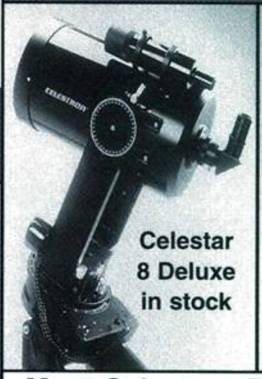

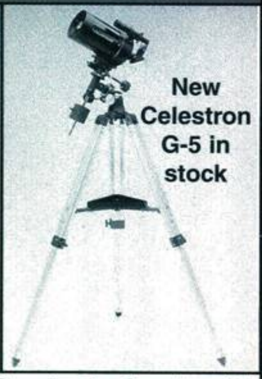

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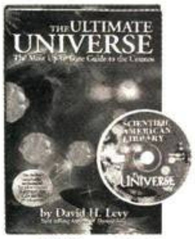
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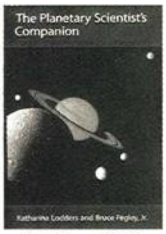
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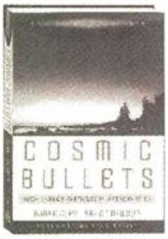
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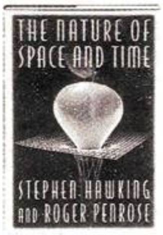
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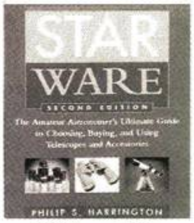
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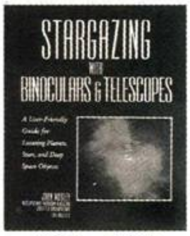
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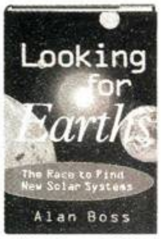
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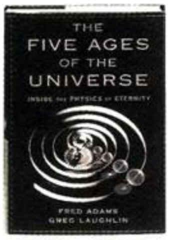
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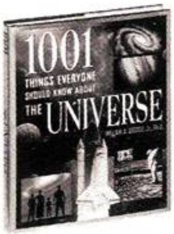
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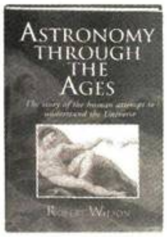
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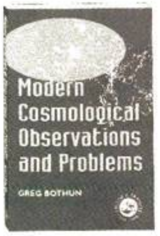
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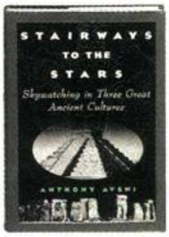
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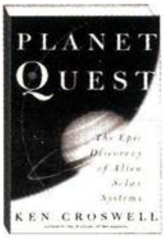
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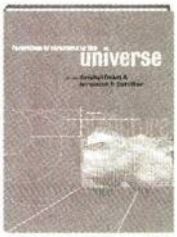

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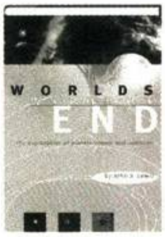

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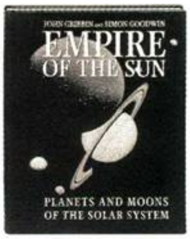
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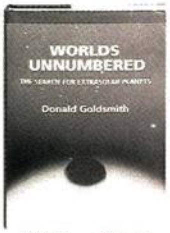
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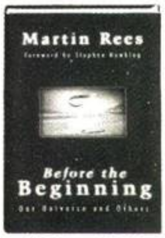
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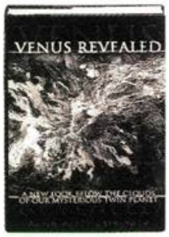
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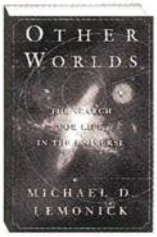
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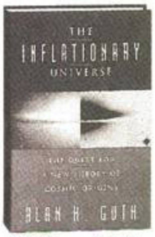
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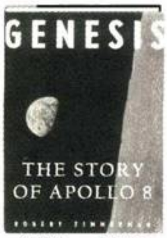
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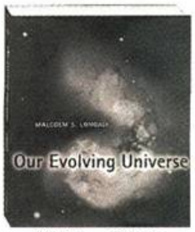
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Orion SkyQuest XT metal-tube Dobsonian telescopes represent a giant leap ahead in quality and performance over standard Dobs. They boast a durable, enameled-steel optical tube (not spiral-wound paper), which houses expertly crafted parabolic optics guaranteed to be diffraction-limited, for jaw-dropping views of solar system and deep-sky objects. CorrecTension Friction Optimization provides smoother motion and eliminates nagging balance problems. A Teflon-lined aluminum focuser (not plastic), 3-vane secondary mirror holder, improved altitude hub design, and a strengthened, rock-stable base are just a few of many notable features.

Plus, all these great accessories are INCLUDED: 25mm (48x) and 9mm (133x) Plössl eyepieces (1.25"), 6x30 achromatic finder, eyepiece rack, Moon filter, protective dust cap, and Astronomy CD-ROM! Compare to the competition!

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  Two Plössl Eyepieces
  Eyepiece Rack
  Moon Filter, & More!

Orion ShortTube™ 80mm Rich-Field Refractor
NEW LOWER PRICE!

Super-portable 400mm f.l., f/5 scope excels for casual observing and prime-focus astrophotography. Ideal for celestial and terestrial viewing. 6x30 finder, 1.25" rack-and-pinion focuser, 45° erect-image diagonal, and TWO 1.25" Kellner eyepieces. Mounts on a photo tripod or equatorial mount (sold separately). Makes a terrific guide scope, too!

Was $229 **NOW $199**

Glass Solar Filter	$59.95

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Now with Plössl eyepiece!

Not an expensive techno-toy, just the most portable 90mm refractor ever. Less than 20" long, but packs 27% more light-gathering capability than an 80mm refractor. Its 500mm focal length (f/5.5) provides gorgeous wide-field views. Includes 6x30 finder, 26mm (19x) Plössl eyepiece, 1.25" star diagonal, rack-and-pinion focuser, 1/4"-20 baseplate. Tripod/mount sold separately.

ONLY $329

AZ-3 Altazimuth Mount	$169
EQ-2 Equatorial Mount	$149

Orion Explorer™ 90mm Altazimuth
NEW LOWER PRICE!

For scenic viewing in daylight or casual evening starwatching, you can't beat it! Nor can you beat its price. Precision 90mm multi-coated achromatic refractor on new AZ-3 altazimuth mount, featuring dual slow-motion cables and adjustable aluminum tripod. Complete with 25mm (36x) and 10mm (91x) Kellner eyepieces (1.25"), 45° correct-image diagonal, 6x30 finder, and accessory tray. Focal length 910mm (f/10).

Was $359 **NOW $339**

Argonaut™ 150mm EQ Maksutov-Cassegrain
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The design heralded for its extraordinary image quality is now very affordable. Now comes with precision SkyView Deluxe equatorial mount and gold-anodized aluminum tripod. Effective focal length is 1800mm (f/12), 150mm (nearly 6") aperture. Gearless Crayford 2" focuser, 7x35 achromatic finder, and padded case for OTA.

Was $1099 **NOW $1069**
Tube Assembly only ~~$899~~ $869

"... visual performance similar to a 4-inch apochromatic refractor costing more than 2-1/2 times as much."
Sky & Telescope (4/99)

Star diagonal and eyepiece sold separately.

Orion Skywatcher™ 120mm (4.7") EQ Refractor

Big-aperture refractor that excels for lunar and planetary viewing, and for deep-space targets too dim for smaller refractors. Multi-coated 120mm achromatic objective lens. The 2"-diameter drawtube accepts 2" or 1.25" accessories. Includes 6x30 finder, 90° mirror diagonal, multi-coated 20mm (50x) and 10mm (100x) Plössls (1.25"). Beefy EQ-3 equatorial mount with aluminum tripod. FREE polar-alignment scope! Dual-axis motor drive optional. Focal length 1000mm (f/8.3).

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More compact than the original Little Giants. Big 70mm objectives reveal a plethora of nebulous clouds and stellar clusterings. Great for twilight and daytime use too. Sharp, fully multi-coated optics with BAK-4 prisms. Large, knurled center focus wheel. Classic black coarse-grain finish. Tripod L-adapter, case, and deluxe wide neck strap included. Made in Japan.

11x70 4.5° field	$259
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20x70 3.0° field	$259

NOW WITH BAK-4 PRISMS!

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Newly upgraded with BAK-4 prisms for improved images. Multi-coated optics. Metal housing, not plastic. Tripod adaptable. Terrific price! Great gift.

7x50 7.1° field
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NEW TWIST-LOCK EYECUPS!

UltraView™ 50mm

Extra-long 22mm eye relief makes these superb for eyeglass wearers! Fully multi-coated optics, BAK-4 prisms. New twist-lock eyecups. Tripod adaptable.

7x50 6.5° field	$169
10x50 WA 6.5° field	$169

9x63 IMPROVED OPTICS!

Mini Giant™ Binos

Compact astro binocs that show you the light! Fully multi-coated optics, BAK-4 prisms. Long eye relief (8x56: 18mm, 9x63: 26mm). Easily hand-holdable, but also tripod adaptable.

8x56 5.8° field	$159
9x63 5.0° field	$189

TRIPOD L-ADAPTER INCLUDED!

Giant 80mm

Stunning resolution of clusters, nebulas, and lunar surface detail. Fully multi-coated optics with BAK-4 prisms. Objective bridge for added rigidity. Center focus. Tripod L-adapter included. Long 15mm-16mm eye relief.

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16x80 3.5° field	$379
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SuperGiant™ 100mm

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Gigantic 100mm (almost 4") lenses for unbelievably detailed views of the heavens! Fully multi-coated optics with BAK-4 prisms. Platform-type 1/4"-20 mounting plate included. Comes with foam-lined aluminum case.

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Individual focus. 3.3° field,
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An unforgettable visual experience! Uses interchangeable 1.25" telescope eyepieces, allowing wide range of powers! Includes two 25mm eyepieces (36x, 1.1° field). Mount/tripod sold separately.
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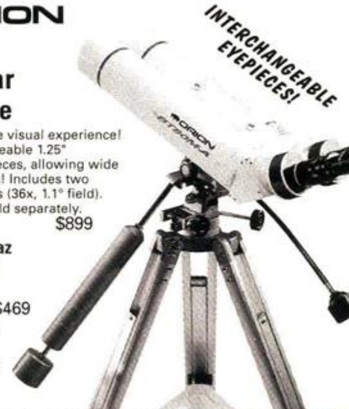

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The most powerful truly portable binocular you can buy! Whopping 4.9" multi-coated front lenses of 625mm focal length (f/5). High-power images so bright, sharp, and resolved they'll knock your socks off! Rigid altazimuth fork mount features friction control on both axes, and allows pointing to zenith. Adjustable aluminum tripod. Weighs 24 lbs.

20x125 BT
Fixed 20x power, nice 3.0° field of view, 20mm eye relief.
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Variable-Power BT
Four fixed powers: 25x, 38x, 50x, and 75x! Field of view 1.6° at 25x, 0.8° at 75x.
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Sirius™ Plössl Eyepieces

You could pay twice the price for other brands of Plössl eyepieces, but why? Sirius Plössls are top-quality, 50° apparent-field (43° 40mm) eyepieces that yield extremely sharp images of impressively high contrast. Ideal for all types of telescopes. Fully-coated optics, rubber eyeguards.

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6.3mm, 7.5mm, 10mm, 12.5mm, 17mm, 20mm, 26mm $49.95 each
32mm, 40mm $59.95 each

.965"
6.3mm, 7.5mm, 10mm, 12.5mm, 17mm, 20mm, 26mm $49.95 each

Ultrascopic™ Eyepieces

The highest contrast and light transmission obtainable. Superior 5- or 7-element design with Ultra Multi-Coatings on every surface. Wide 52° apparent field. Removable winged rubber eyeguard. Threaded for filters. 1.25" barrels.

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Attractively priced for even limited budgets. Their 3- and 4-element fully coated glass lens configurations provide a 50° apparent field of view. Threaded for filters.

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6mm, 10mm, 13mm, 17mm, 25mm
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Fully multi-coated 2" deep-sky eyepieces that render magnificent scenes of deep-space objects framed in a generously wide swath of starry backdrop. The 50mm is a modified Plössl design with 45° apparent field; the 32mm and 40mm are four-element designs with fields of 58° and 62°, respectively.

Manufactured in Japan. Threaded for filters. For use in 2" holders.

50mm	$119
40mm	$139
32mm	$129

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Orion Lanthanum Eyepieces

Our rare-earth lanthanum eyepieces have new chrome exteriors but the same superior image correction and generous 20mm eye relief of the previous models. Ideal for eyeglass wearers! Fully multi-coated optics with six to eight lens elements. Apparent field 50° (7.5-25mm), 45° (2.3mm-5.2mm). Pop-down rubber eyecups. Made in Japan. 1.25" barrels.

3.8mm, 5.2mm, 7.5mm, 9.5mm, 10.5mm, 12.5mm, 14mm
$109 each

2.3mm, 21mm, 25mm
$119 each

Lanthanum 65° Superwides

Combining long 20mm eye relief, an expansive 65° apparent field, and a rare-earth lanthanum lens element for superior image correction, these oculars are an astronomer's dream come true. Eight lens elements, multi-coated. Fit 1.25" or 2" focusers.

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$214 each

17mm, 22mm $222 each

SkyGlow™ Broadband LP Filters

Improves contrast of all objects in moderately light-polluted skies.

.965" $44.95,
1.25" $59.95,
2" $109, SCT Rear Cell $89.95

UltraBlock™ LP Filters

Maximum contrast enhancement for emission nebulas.

.965" $79.95, 1.25" $99.95
2" $139, SCT Rear Cell $129

Moon Filters

Cut lunar glare to reveal much more surface detail.

.965", 1.25" $15.95 each

Ultrascopic™ 3-Element 2x FMC Barlow

Our most advanced barlow employs 3-element, fully multi-coated lens system with 27mm clear aperture. Renders images of high fidelity with superior color correction. Provides 2x power boost to any 1.25" eyepiece.
$69.95

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Doubles the power of any eyepiece. Just 2-7/8" long.

.965", 1.25"
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Optical Tube — Celestron's legendary 5" 1250mm f/10 Schmidt-Cassegrain optics is noted for its razor sharp image quality. The large 5" aperture allows you to clearly view deep space objects like galaxies, nebulae, clusters and double stars. An optional f/6.3 Reducer/Corrector provides a wider field and faster imaging.

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The new Celestron NexStar 5 Schmidt-Cassegrain Telescope takes simplicity of use into a new dimension. A design and engineering tour d'force, the NexStar 5 combines a unique sculptured fork arm and drive base, state-of-the-future electronics, advanced mechanical engineering, and Celestron's renowned optics. Add to that an array of operation, convenience and software features that are optional or unavailable on most other GOTO telescopes. The result is nothing less than the perfect telescope for the first-time buyer who wants to start touring the Universe with virtually no learning curve or complicated set-up, or the serious amateur looking for advanced features not found on other GOTO telescopes.

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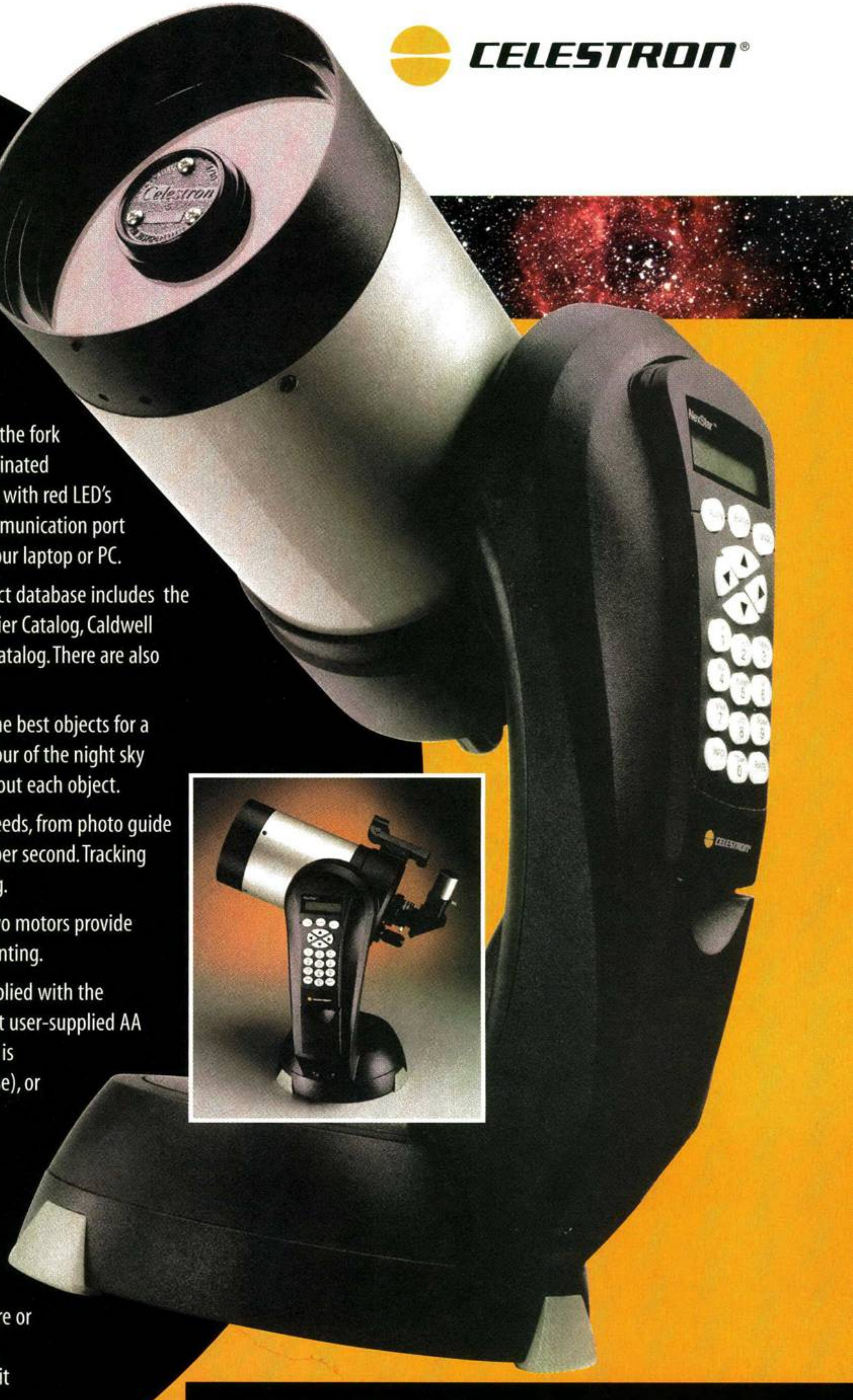

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For long exposure astrophotography or CCD imaging, use the telescope in the equatorial configuration by adding an optional wedge.

The heavy duty fork mount is extremely rigid and sits on top of a sturdy, adjustable metal tripod. Yet, the telescope is extremely portable and convenient to take with you.

Two motors per axis are standard as well as precision worm gears in both axes that provide very smooth, accurate tracking ability.

The Ultima 2000 can be moved manually (by hand) without losing its star alignment.

SOFTWARE / ELECTRONICS FEATURES

The power efficient DC telescope is operated with the included AA batteries. A built-in voltmeter monitors the status of the batteries. Optional adapters are available to run the telescope from a car battery or from an AC power source.

The standard, compact hand controller operates the various functions such as position, identify, speed, pointing, etc.

8 tracking and slewing speeds are available – sidereal, solar, lunar, King, 2x sidereal, 0.5x sidereal, 2° per second, 10° per second.

The Ultima 2000 has impressive pointing accuracy where the object selected will always be in the field of view of a low to medium power eyepiece. Includes Enhanced Encoder Resolution and Relative Go To mode for increased accuracy which is ideal for centering objects on a CCD chip.

The software database contains over 10,000 deep-sky objects as well as major planets. The objects include the entire Revised New General Catalog, the Messier catalog, selected objects within the IC catalog and the ESO and Uppsula catalogs, 241 interesting double and multiple stars, and 661 non-stellar objects. The database may not be the largest in the industry but it is one of the most useful because of the object selection. In addition, the display of the object data is the most complete of any commercial computerized telescope.

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The Ultima 2000 can by operated by a computer using popular astronomy software such as *The Sky*. Programs can also be written by the user to control the telescope.

Other standard features and accessories include: 9x50 finderscope, multi-coated 26mm Plössl eyepiece – 1¼" (78x), star diagonal – 1¼", LED display, auto guider port, northern and southern hemisphere operation, comprehensive instruction manual.

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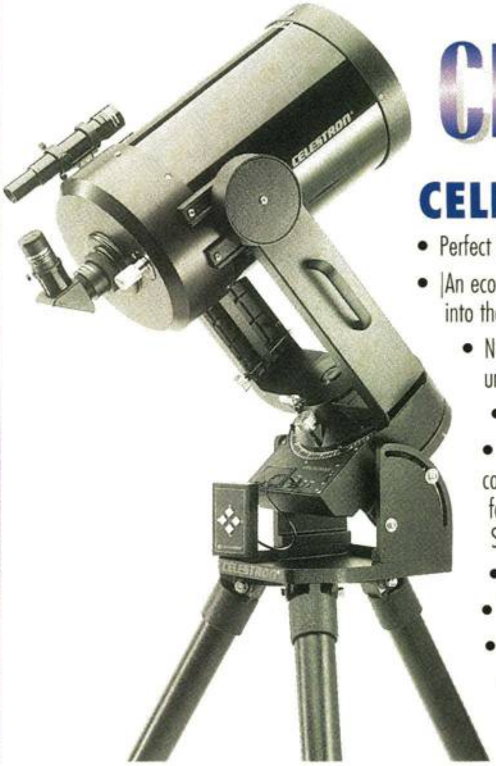

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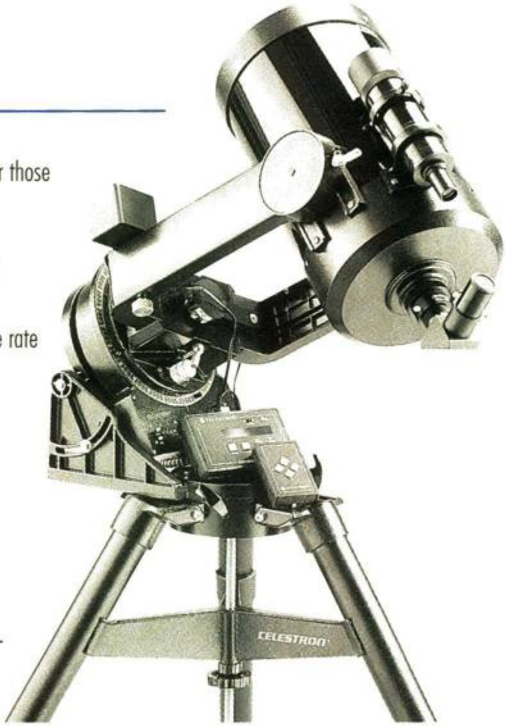
- The unique Wedgpod is a combination tripod and wedge which is very stable.
- Made in the U.S.A.
- Standard accessories include: 6x30 Finderscope, Star Diagonal – 1¼" and a 25mm SMA Eyepiece – 1¼" (81x).
- Weight – 41 pounds.

CELESTAR 8 DELUXE



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- This telescope utilizes the same superior optics and has all the features of the Celestar 8, but is enhanced, for those who prefer a premium version.
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- Superior tracking accuracy is attained with this advanced drive system, which has four tracking rates and PEC (Periodic Error Correction).
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- Fastar compatible for f/1.95 CCD imaging – deep sky images in 30 seconds or less!
- Made in the U.S.A.
- The standard accessories for this telescope include: Declination Motor, Car Battery Adapter, Hand Controller, Wedge and a Tripod with adjustable height that's exceptionally rigid and sturdy .
- Also standard is a large 9x50 Finderscope, Star Diagonal – 1¼" and a multi-coated 26mm Plossl Eyepiece – 1¼" (78X).
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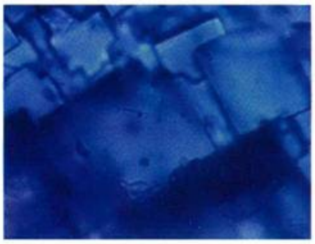
REVEALING ROCKS

Asteroid Genealogies Come into Focus



Above Left: Asteroid Braille as photographed in July by Deep Space 1. NASA

Middle: This meteorite, which in 1960 fell in western Australia, is a chip off the asteroid Vesta. Photograph courtesy of Russell Kempton (New England Meteoritical Services)

Above Right: The Monahans, Texas, asteroid is laced with halite, common salt, which contains water in tiny bubbles. The halite crystal is bluish-purple due to the cumulative effects of about 4.5 billion years of exposure to solar radiation. Michael E. Zolensky (JSC) et al., NASA

▶ Nearly two centuries after Giuseppe Piazzi discovered the asteroid Ceres, new discoveries are leading astronomers to call asteroids messages in bottles, chips off the old blocks, and members of shattered families. Space rocks are hot.

Geologists recently found tiny bubbles of water in a meteorite that fell to Earth in March 1988 in Monahans, Texas. A team led by Michael Zolensky reported in *Science* that the 2-pound object contains the bubbles inside halite (table salt) crystals embedded in the meteorite. The water could have coalesced within an asteroid with other primordial ingredients, or it could have been deposited later due to a comet impact. Since the tiny amount of water in the halite could be as old as the solar system — about 4.5 billion years old — astronomers regard it as a message in a bottle. At some point a much larger parental asteroid probably was broken up in a collision and one small piece ended up in the Lone Star State.

Researchers who guided the Deep Space 1 probe to within about 16 miles (25 km) of asteroid 9969 Braille also found evidence of an asteroid breakup. Previously known as 1992 KD, astronomers renamed the object Braille in honor of the 19th-century, blind French educator Louis Braille. (He devised the system of printing for blind readers that uses characters made of raised dots.) The NASA satellite snapped fuzzy pictures of the asteroid in July. The craft's infrared spectrometer — an instrument that splits infrared light into its constituent wavelengths and measures the brightness of each one — found clues that Braille is strikingly similar to the asteroid Vesta. Scientists now are trying to determine if Vesta is Braille's "parent" or whether the two are siblings formed during the breakup of a larger body.

Massachusetts Institute of Technology astronomer Schelte J. Bus says many asteroids that orbit the sun do so in groups known as "families." Like asteroid Braille, at least 19 families of asteroids were chipped off parental blocks during violent collisions long ago.

Bus also used spectroscopy to analyze thousands of asteroids that apparently orbit the sun as members of identifiable families. Different materials reflect different amounts of each color, and this property enabled Bus to accurately determine each asteroid's chemical composition.

He found that most members of any one family share the same constituents and that each family has a makeup that is distinct from that of other families. He says the most likely explanation for the genealogical differences is that each family was generated by its own parent asteroid that was shattered by a collision, forming a stream of similar fragments, all possessing similar orbits. "The work of Bus now puts on solid ground that clumps of asteroids that had been seen as families are indeed genetically related," says astronomer Richard Binzel, also of MIT.

— PAUL PARSONS

SLOW POKE

Sluggish Pulsar Puzzles Theorists

▶ Australian astronomers have discovered a pulsar — a compact, highly magnetized radio-wave-emitting star — that is spinning slower than most theorists thought possible while also still emitting radio pulses. The pulsar — PSR J2144–3933 — emits radio pulses once every 8.51 seconds with each complete rotation. It is the slowest spinning pulsar discovered to date.

Huge supernova explosions generate highly compact neutron-star cores. A pulsar forms because these bizarre objects, only 6 to 12 miles (10-20 km) in diameter, spin faster as they collapse, just as a twirling figure skater spins faster as she pulls in her arms. The pulsar's magnetic field — a million times stronger than Earth's — and its speedy rotation combine to accelerate electrons. The acceleration leads to the emission of radio waves in a narrow beam that sweeps across space like the rotating beam of a lighthouse. Astronomers observing the pulsar can detect the radio pulses each time the beam sweeps across Earth.

The most rapidly spinning class of pulsars — millisecond pulsars — flash

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G-8

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G-8N

MOUNT: All three telescopes use the CG-5 German mount. The CG-5 mount is the newest generation of Celestron's German mounts which was designed by Celestron and replaces the old style, outdated GP mounts. Both axes of the equatorial mount have precision worm gears for extremely smooth motion and excellent tracking accuracy.

This heavy-duty mount easily delivers jitter-free images and the sturdy adjustable height aluminum tripod has excellent damping characteristics. A convenient deluxe accessory tray adds to the stability of the system.

ACCESSORIES: Numerous accessories are available for these telescopes. Included as standard eyepieces – 25mm SMA - 1¼" (81x) on the G-8, 26mm Plössl - 1¼" (90x) on the G-9¼ and 20mm Plössl - 1¼" (50x) on the G-8N. The standard finderscope is a 6x30 with the G-8 and G-9¼ and a 9x50 with the G-8N.

Some of the more useful accessories for these telescopes are the polar alignment scope (for fast polar alignment) and DC motor drives for automatic tracking of celestial objects. Celestron offers a choice of motor drives – a single axis (R.A.) or dual axis. They are powered by four D-cell batteries (not included). Both models include a hand controller with built-in drive corrector for astrophotography.

Computerize your telescope by adding the optional Advanced Astro Master® which is easily installed. Its pointing system contains a data base of over 10,000 objects. Once aligned, it will guide you to any one of these objects. Included are the entire RNGC catalog, the Messier catalog, IC catalog (selected objects), major planets, over 241 interesting double and multiple stars and a user definable catalog of 25 objects. Operates on a standard 9V battery. Contains an RS-232 serial interface to enable usage with programs like "The Sky" by Software Bisque.

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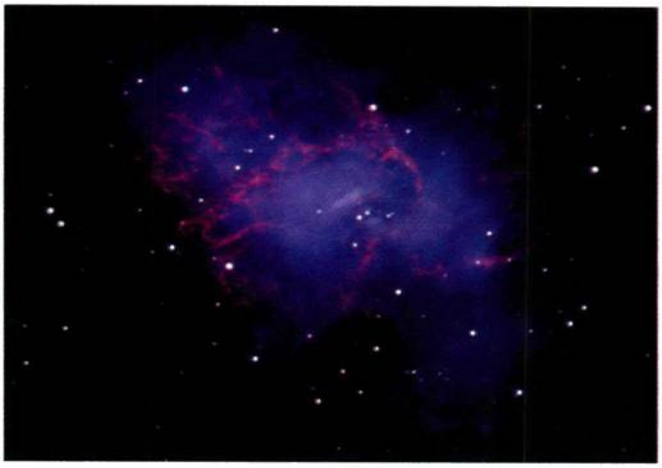


A pulsar with a radio-emitting pulse period of 0.033 second lies within the center of the Crab Nebula, the glowing remains of a supernova explosion. Bill Schoening, AURA, NOAO, NSF

as rapidly as once every 0.0016 second. However, most known pulsars rotate roughly once every second. Theorists think a slow-spinning pulsar can accelerate to become a millisecond pulsar billions of years after it forms by pulling mass from a companion star that has become a red giant. However, most pulsars slow with age and, at some point, their radio pulsations cease.

The pulsar J2144–3933 was discovered in the constellation Grus in 1993. Astronomers initially thought it had a rotational period of 2.84 seconds. However, the initial determination was faulty because the software used at the time did not measure rotational periods as long as 8.51 seconds. "They set a cutoff between 5 and 6 seconds to try to get rid of noise and low-frequency variations," says the leader of the Australian team, Matthew Young of the University of Western Australia in Nedlands. "I wasn't expecting to make this discovery. Then it became evident that the period was *three times* longer than the accepted value," he says. Young and his colleagues, who reported their results in the August 26 issue of *Nature*, plan to look for other pulsars whose long periods also may have escaped detection earlier in a similar fashion.

Theorists had predicted that a neutron star rotating as slowly as J2144–3933 would not produce radio pulses. "This object should not exist according to the criteria of why we see radio pulsars," says Vicky Kaspi, an astrophysicist at the Massachusetts Institute of Technology in Cambridge.

Kaspi has submitted a proposal to use the Arecibo Observatory, a radio telescope in Puerto Rico, to also look for long-period pulsars. "It is very possible that there are more. . . . They may have been overlooked because nobody was expecting them to be there," says Kaspi. Theorists will have to look for an explanation. "We just have to start at the drawing board, back to basics," she says. Young agrees. "We need to go back and look carefully at the theory," he says.

—ALEXANDER HELLEMANS

MYSTERY OBJECTS

Spectrum Solves Stellar Mystery

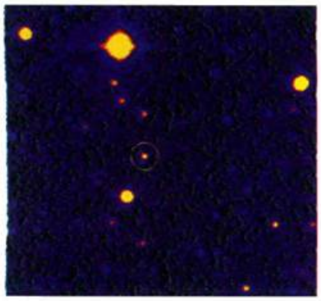
▶ The public loves a mystery. Caltech astronomer S. George Djorgovski perceived that truism during the months after he announced in May his group's discovery of a "mystery object" in the northern sky. Reporters requested interviews. Nonscientists called to discuss their private UFO theories. "Somebody even sent me an idea that it was the New Jerusalem coming toward us — with biblical references," says Djorgovski.

His mystery object, photographed several years ago, was one of billions of stars and other astronomical objects being catalogued as part of the Digitized Palomar Observatory Sky Survey. Djorgovski's group noticed that one object in Serpens was oddly colored. The astronomers used the Palomar Observatory's 200-inch (5-m) Hale Telescope to break down the star's visible light into its component wavelengths. Such an information-rich spectrum contains patterns of peaks (of light emissions from various elements and molecules) and valleys (often of absorptions caused by material between the light source and Earth). Spectra can be used to identify and study everything from asteroids to galaxies. However, the spectrum of the mystery object was unique. Had Djorgovski stumbled upon an entirely new type of object?

Djorgovski suspected it was a rare object called a broad-absorption-line quasar. Quasars are thought to be the centers of the universe's earliest, and hence very distant, galaxies. They are powered by supermassive black holes that are drawing in matter at a colossal rate and emitting prodigious amounts of radiation in the process. Because of the expansion of the universe, light from quasars is redshifted to longer wavelengths in proportion to their recessional speeds. About 10 percent of highly redshifted quasars have spectra with unusually broad absorption lines. The origin of these broad lines remains a mystery, but it could be the result of high-speed winds or disrupted stars in the vicinity of the quasar's black hole.

To test his hunch, Djorgovski asked astronomers Fred Chaffee and Tom Bida to take a spectrum in infrared light with the 10-meter Keck Telescope in Hawaii. Their spectrum showed a prominent emission line from hydrogen, which is typical of all quasars. Djorgovski says highly ionized, iron-rich gas between the quasar and Earth may be absorbing some of the quasar's light, generating its unusual visible-light spectrum.

The mystery object discovered by Caltech astronomers could be an unusual quasar. S. George Djorgovski (Caltech), et al., DPOSS Team



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But while one mystery was apparently solved, two additional, recently discovered objects remain unidentified. The visible-light spectra of these objects not only look entirely different from that of Djorgovski's object, they also don't resemble each other.

Princeton University astronomers Xiaohui Fan and Michael Strauss found the two objects while examining data from the Sloan Digital Sky Survey (see "Stars and Strips Forever," February 1999). Once again, the objects have spectral features that indicate they are highly unusual astronomical objects.

"We have no idea what they are," says Fan. "People have suggested that they could be quasars, or active galaxies." He suspects that one of the objects is a white dwarf with a very strong magnetic field.

The Sloan Survey has only recently gotten underway, so Fan says it could easily turn up many more mystery objects. "I think it is totally expected that we'll find something totally unexpected," he says.

Djorgovski says that large sky surveys such as the Sloan and Palomar surveys, and several others that are mapping the sky at different wavelengths, most likely will herald an exciting new era for astronomy.

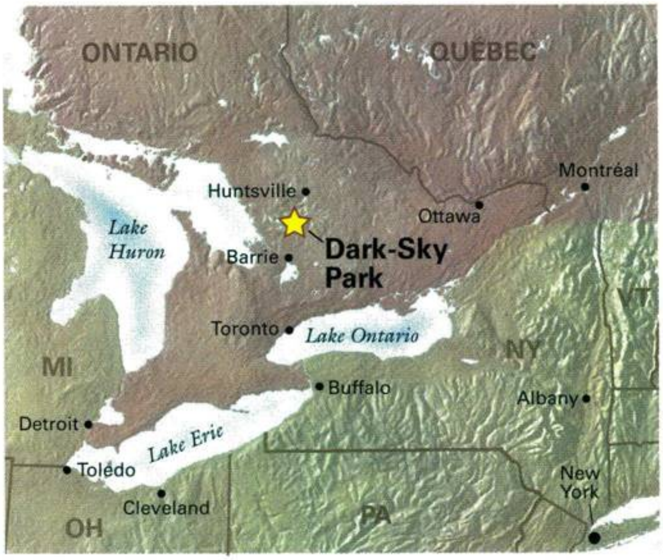
Data from these digital surveys will be available to fellow astronomers and the public via the Internet. "Someday, we'll be able to create a virtual national observatory," says Djorgovski. "We'll be able to find all sorts of new, interesting, rare types of things." To search the Palomar Sky Survey website, go to http://astro.caltech.edu/~rrg/science/dposs.html.

LIGHT POLLUTION

Canadians Create Dark-Sky Preserve

▶ The Ontario, Canada, Provincial Government in July created the world's first dark-sky preserve. The government imposed a "permanent blackout" within a remote public area in the south-central part of the province about 150 miles north of Toronto. The 4,900-acre, dark-sky preserve is part of the province's Torrance Barrens Conservation Reserve. The Township of Muskoka Lake, a community southeast of the reserve, also has approved a plan to regulate development to control light pollution, and Gravenhurst, a larger city east of the unspoiled reserve, is studying similar controls.

Many applaud the effort to establish a dark oasis for amateur astronomers north of the Canada-United States border. "It's an acknowledgment by provincial and municipal governments of the importance of preserving the skies for future generations," says Canadian astroimager Jack Newton. "I hope we can use this initiative as a lever to enable more groups and individuals to encourage other governmental bodies to take similar action."



Astronomy: Elisabeth Rowan

The Canadian government's decision came one month after voters in Springfield, Vermont, narrowly approved a plan to build a nearby 350-bed state prison. Amateur astronomers say the prison's lights could hurt the nighttime views at Stellafane, a historic observatory and the site of an annual telescope-making meeting and star party. In a September 14 revote, Springfield citizens again approved the prison plan 2,332 to 1,545.

The rugged Torrance Barrens area has granite outcrops, sparse vegetation, and stunted trees. "When you climb one of the outcrops, the view is clear from horizon to horizon," says Peter Goering. He and the Muskoka Heritage Foundation, of which he is a member, spearheaded the effort to save the reserve from light pollution.

"Ontario's Provincial Government was looking at different ways to develop publicly owned lands. This included logging and mining," says Goering. "My wife and I have lived in the Muskoka Lake area for 48 years, and we've watched the skies deteriorate."

Goering notes that the recent victory for amateur astronomers will be a hollow one if the surrounding towns are unable to control light pollution. Goering and his colleagues vow to continue the fight to protect the observer's paradise.

— Andrea Gianopoulos

ASYMMETRY

Hourglass Nebula Defies Explanation

▶ A shimmering hourglass 8,000 light-years away, the planetary nebula MyCn 18, is striking in its beauty and complexity. However, the only time this hourglass can keep is the death knell of a star, and it is so odd that astronomers say it is forcing them to rethink the physics that shapes it.

Not only does MyCn 18 display a second, smaller hourglass of gas inside the larger one, but neither hourglass is positioned symmetrically around the central star. The central star is a white dwarf, a very hot, compact, spent star that wouldn't have enough gas remaining to generate such an extraordinary nebula.

"What we thought we understood of planetary nebulae we no longer do," says Raghvendra Sahai, an astronomer at the Jet Propulsion Laboratory in

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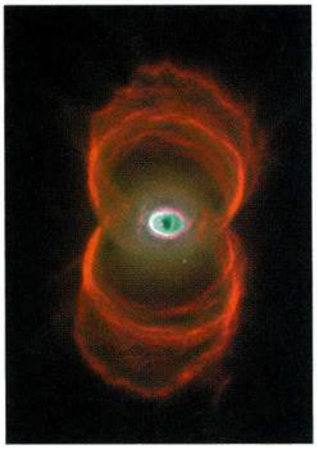


This image taken by the Hubble Space Telescope's Wide Field and Planetary Camera 2 reveals the true shape of MyCn 18 to be an hourglass with an intricate pattern of "etchings" in its walls.

Raghvendra Sahai and John Trauger (JPL), the WFPC2 science team, and NASA

Pasadena, California. "Something different and dramatic is going on."

The asymmetrical hourglass architecture and revealing images obtained by the Hubble Space Telescope are spawning a renaissance, he says, in the study of planetaries. They form when an aging ordinary-mass star, having exhausted most of its nuclear fuel, starts to expand into a red giant. Escaping gas and dust accumulate first as a belt around the equator of the star. As the volume of escaping gas increases, the belt constricts the star's midsection and forces the increasingly fast-moving gas into an hourglass shape. The escaping gas, heated and ionized by the dying star, shines. However, MyCn 18 may very well be a highly unusual planetary.

Sahai and others reported in the July issue of *The Astronomical Journal* that MyCn 18 must result from a binary-star system. They argue that the nebula needs a source of a lot of gas, one that a white dwarf alone would lack. Gas escaping what might be a nearby red giant (or alternatively a smaller, dim, Jupiter-sized star) could be sucked onto the dwarf where it could accumulate and eventually fuel a nova explosion, the gas of which would spread outward to form the hourglass.

The second hourglass is more difficult to explain. "It's very hard to see how you get it," says Sahai. "You just don't have enough material."

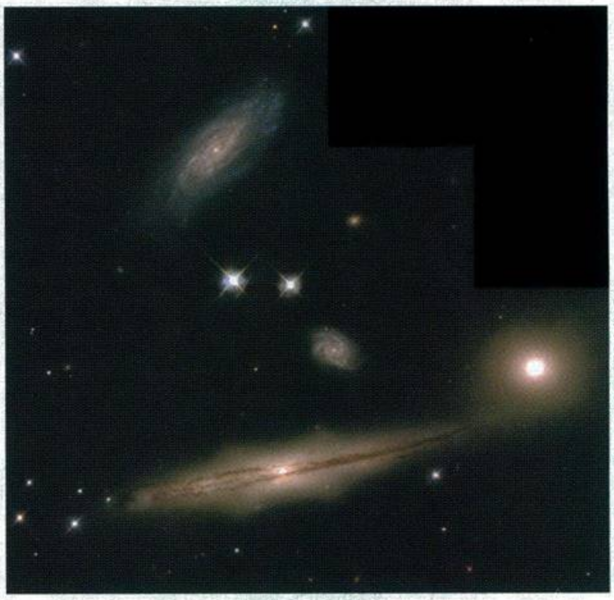
Astronomers say that perhaps the explosion itself was asymmetrical. Arizona State University astronomer Paul Scowen theorizes that the interstellar medium around the star system itself may have been inhomogeneous, allowing the expanding nebula to form asymmetrically.

The intrigue continues. Astronomers used Hubble to captures two other rings at the neck of the hourglass — possibly a belt of dense gas escaping the unseen star and a second ring perpendicular to it. What forces are responsible for the rings? "We have no idea," says Sahai. "We have to make a fresh start to understand the physics of planetary nebulae."

"This nebula has caused a lot of speculation," says Scowen, "and for now it is just speculation." Meanwhile, he is fascinated by the intricate pattern of rills and ripples set up in the gas at the upper reaches of the nebula, created by turbulence. Planned computer simulations that test various theories might give a clearer explanation of just how the puzzling, stunning nebula was sculpted.

— David Graham

GALAXY GROUP



The Hubble Heritage Team (AURA, STScI, NASA)

THESE GALAXIES ARE PERFORMING an intricate dance orchestrated by their mutual gravitational attraction. The galaxies, known as Hickson Compact Group 87 (HCG 87), were photographed by Hubble Space Telescope's (HST's) Wide Field and Planetary Camera 2. The group's largest galaxy member (HCG 87a) is disk-shaped but tilted so that we see it nearly edge-on. Both 87a and its elliptically shaped nearest neighbor (87b) have active nuclei, central regions that are believed to harbor black holes consuming gas. A third group member, the nearby spiral galaxy 87c, may be undergoing an active burst of star formation. The small spiral near the center of the group is either the fourth member or an unrelated background object. HCG 87 was voted a favorite HST image by members of the public who visited the Hubble Heritage website (http://heritage.stsci.edu) in May.

MICROLENSING

Distant Planet Orbits Two Stars

► An unusual flicker in the light from a distant star was most likely caused by the gravity of an intervening Jupiter-sized planet that orbits a pair of stars, reports the Microlensing Planet Search (MPS) collaboration in *Nature*. If confirmed, the finding would be the first discovery of a planet with the so-called gravitational-microlensing technique and the first discovery of a planet that appears to be orbiting a binary star.

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time. "It's like putting a bowling ball on a mattress," says University of Washington astronomer Andrew Becker. Like moving a magnifying glass past a light bulb, this spacetime distortion can cause a star to appear to brighten and fade. Astronomers search for this gravitational-microlensing effect while observing tens of millions of stars a night.

On June 19, 1997, the Massive Compact Halo Object (MACHO) survey team saw a star nearly 28,000 light-years away in the bulge of the Milky Way suddenly brighten about 45-fold. It was the telltale sign of a gravitational-microlensing event. Within 10 days, however, astronomers realized that the bright flickering of the object called MACHO-97-BLG-41 was too complex to be caused by just a single intervening star.

Computer modeling by the MPS team revealed that it took three objects to match the complex pattern of flickering. The most likely object that caused it is a trio — two dwarf stars and a planet weighing three times as much as Jupiter. The stars are separated by 1.8 astronomical units (1 AU is the distance separating Earth and the sun, 93 million miles), and the planet orbits the star system at a distance of 7 AU. "We have several hundred data points," says Becker, "and they constrain the model very well."

"It's a pretty nifty result," says University of California at Berkeley astronomer Geoff Marcy. If confirmed, says Marcy, "it will add an exclamation point to the suspicion that planets can orbit outside binary stars."

— Mark Sincell

SMOKING GUN

A Black Hole's Lost Supernova

▶ Small stars cool off and glow like cinders for eons, but stars with masses 10 times that of our sun explode violently as supernovae, leaving behind a neutron star. They also can leave a black hole — or can they?

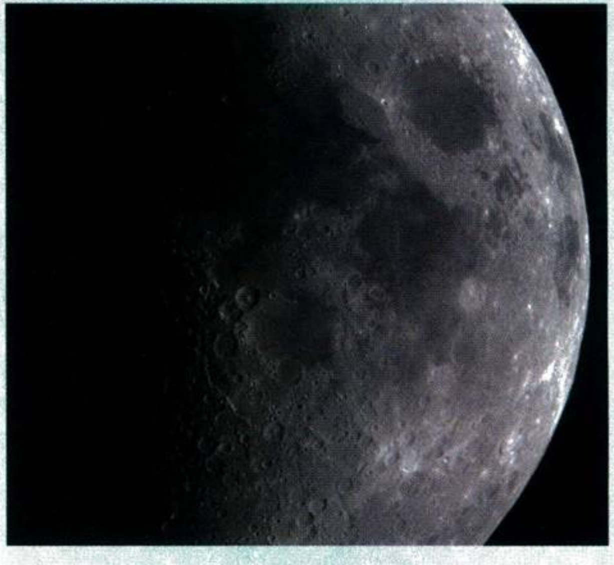
Neutron-star remnants of supernova explosions, such as the Crab Nebula and its central star, have been directly observed. However, no such direct evidence had been found of a supernova leaving behind a black hole. Some scientists believe that a supernova is not even required to generate a black hole; a star may just contract gravitationally into one.

Now astronomers in Spain have found strong circumstantial evidence of a black hole that has been formed by a supernova. They observed the binary system GRO J1655–40, also known as Nova Scorpii 1994 because it briefly flared x rays that year. The system consists of a central invisible component of four to eight solar masses. A star with 1.6 to 3.1 solar masses circles the central object. "It is one of the best known black-hole binaries in the galaxy," says Rafael Rebolo of the Instituto de Astrofisica de Canarias in Tenerife.

Rebolo and his colleagues reported in the September 9 issue of *Nature* that the companion star clearly bears the chemical imprint of a nearby supernova explosion. "We have found products of the nucleosynthesis during the explosion that were retained by the companion star," says Rebolo. Using the Keck Telescope in Hawaii, they observed unusually high concentrations of oxygen, magnesium, silicon, and sulfur in the star's atmosphere. The abundances of these elements are 6 to10 times higher that those found in other stars such as the sun.

"We have never seen such a star in our galaxy," says Rebolo. From the relative abundances of the various elements, Rebolo's team estimates that the progenitor had a mass of 25 to 40 suns. Most of the mass of the exploding star was ejected as a huge cloud, and the com-

LUNAR SCIENCE



CICLOPS, NASA, LPL

THE CASSINI SPACECRAFT PHOTOGRAPHED THE MOON during its recent Earth flyby on August 18. This composite image, the first real space test of Cassini's imaging system, was made from three narrow-angle images that captured a significant portion of the moon during the flyby. The test was conducted when Cassini flew more than 700 miles (1,120 km) over the Pacific Ocean, while getting a slingshot-like power boost from Earth's gravity field for its long trip to Saturn. "These are the first images taken by Cassini for both photogenic and scientific purposes, and they illustrate that the cameras are functioning beautifully," says Carolyn Porco, leader of the 14-member Cassini Imaging Science Team. The spacecraft was designed for exploring the saturnian system and includes a variety of spectral filters and imaging capabilities. Cassini will search for lightning on Saturn, investigate the meteorology and atmosphere of Saturn and Titan, photograph Saturn's icy satellites, and study the ring system. The imaging system will be further tested and used in studying Jupiter and its satellites and rings during the Cassini Jupiter flyby in late 2000.

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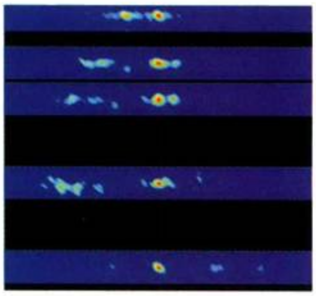


The Milky Way star GRO J1655–40 (central object) spewed huge jets of material at nearly the speed of light. Astronomers discovered it in 1994 with NASA's Gamma Ray Observatory. JPL

panion star apparently absorbed a lot of it. "This is really the first convincing, suggestive evidence that the black hole forms in relationship to the supernova explosion," says John Cowan of the University of Oklahoma in Norman. "The evidence is becoming more convincing that black holes really are there." Rebolo's group currently is investigating two additional binary systems in which a companion star in each has been "smoked" by a supernova. "They are the keys to understanding supernovae," says Rebolo. "We are now investigating even heavier, radioactive elements."

— Alexander Hellemans

COLLISION COURSE

Earliest Galaxies May Have Started Small

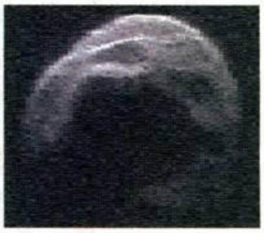
▶ One of the two sides in a healthy scientific debate to explain how the earliest, most-distant galaxies in the universe formed has reported results that support its view that galaxies started small and grew larger by mergers and collisions.

The new results, based on computer modeling and reported in a recent issue of *Astrophysical Journal Letters*, supports what cosmologists call the "collisional-starburst" scenario. This view, championed by coauthors Joel Primack and Sandra Faber, cosmologists at the University of California at Santa Cruz (UCSC), proposes that collisions between small galaxies trigger intense but short-lived bursts of star formation. When two galaxies collide, clouds of gas funnel toward the center of the larger galaxy, and the gas can condense to generate new stars at very high rates.

A competing theory maintains that primordial gas funneled to a central point, where it condensed into stars of high-redshift galaxies. Astronomers call this the "central-quiescent" scenario, because it describes a steady rate of star formation proceeding over a long time.

The paper, titled "Young Galaxies: What Turns Them On?" evaluates the two scenarios that explain the origins of high-redshift galaxies and supports the collisional-starburst scenario. Both explanations include dark matter, mysterious particles that make up 90 percent of the mass of the universe. "The simulation gave us the right numbers, the right clustering properties, and the right brightnesses to explain what we actually see with the telescopes," says coauthor James Bullock of UCSC.

Best Images Yet of a Near-Earth Asteroid



Astronomers using the world's two most powerful radar telescopes made the most detailed images ever of an asteroid in a near-Earth trajectory. The new image was obtained by NASA's Goldstone Solar System Radar in California and the Arecibo Observatory in Puerto Rico. It and other images reveal that 1999 JM_8 is a several-kilometer-wide object with a peculiar shape and an unusually slow and possibly complex spin state. For more, go to http://www.astronomy.com/horizon.html.

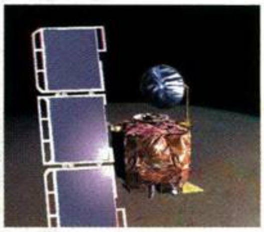
This is a radar image of the newly discovered 1999 JM_8, an unusually large asteroid with a slow rotation rate.

Arecibo Observatory, NASA, JPL

Chemical Similar to Amino Acid Glycine Found in Star-Forming Regions

Formic acid — the colorless, pungent liquid found in ant bites and bee stings — has been found in prodigious amounts at the hot core of the Orion molecular cloud, as well as in similar molecular clouds in Sagittarius called B2 and W51. "In space, formic acid is of great interest because it shares similar structural elements with the common interstellar molecule methyl formate and the biologically important molecules acetic acid and glycine," says astronomer Lewis E. Snyder. For more, go to http://www.astronomy.com/horizon.html.

Mars Climate Orbiter Presumed Lost



Ground communication with NASA's Mars Climate Orbiter ended abruptly September 23 as the craft rendezvoused with the Red Planet after its 286-day journey. The last radio signals indicated that the spacecraft flew about 60 miles (100 km) too low, most likely causing it to crash or burn up in the martian atmosphere. The Orbiter was to serve as a weather satellite for one martian year — almost two Earth years. The spacecraft's loss complicates exploration of Mars because it also was to act as a communications relay for Mars Polar Lander, which is scheduled to land on Mars December 3, and the 2001 Mars Lander. For more, go to http://www.astronomy.com/horizon.html.

The Mars Climate *Orbiter* was *lost upon rendezvous*. NASA

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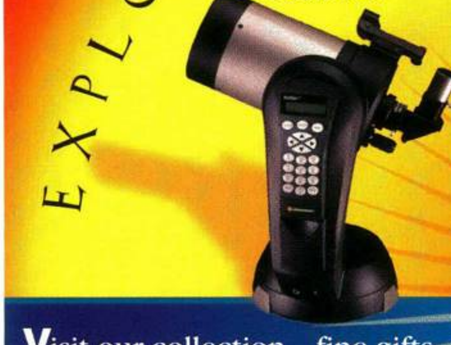

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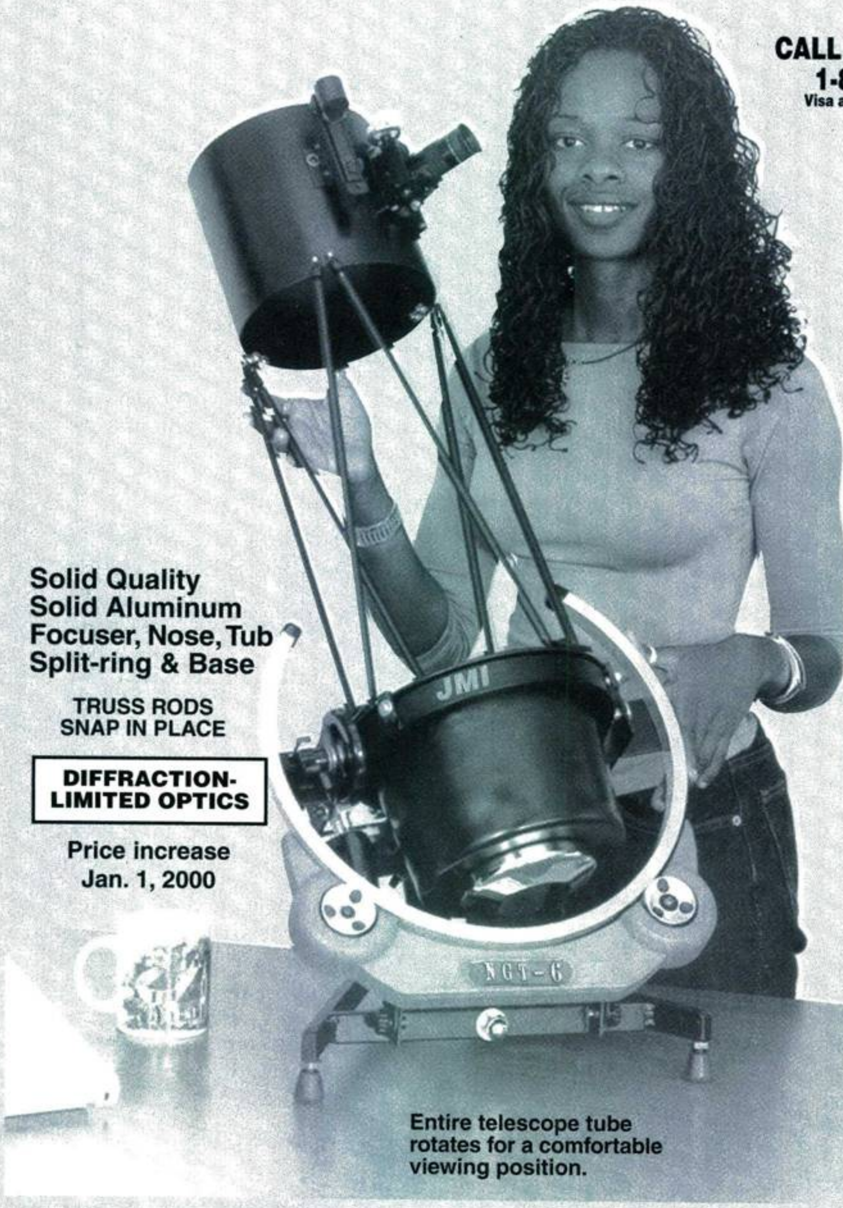

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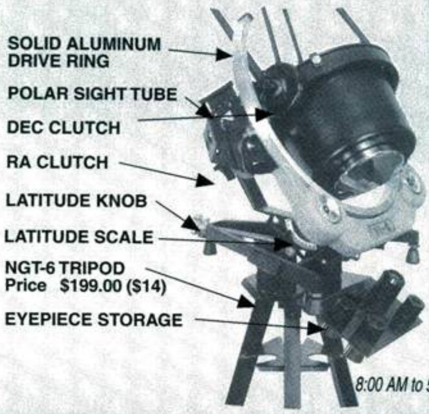

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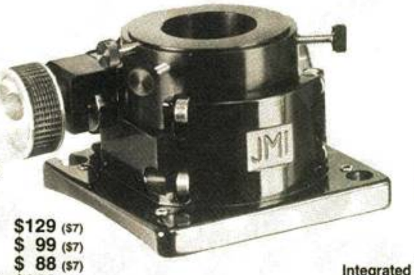

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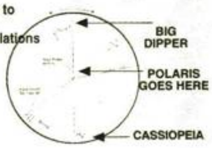

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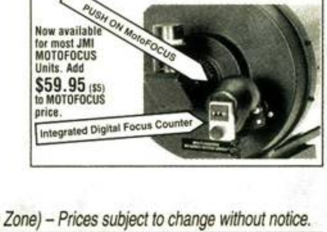

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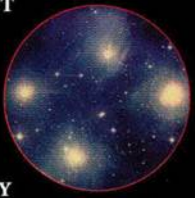
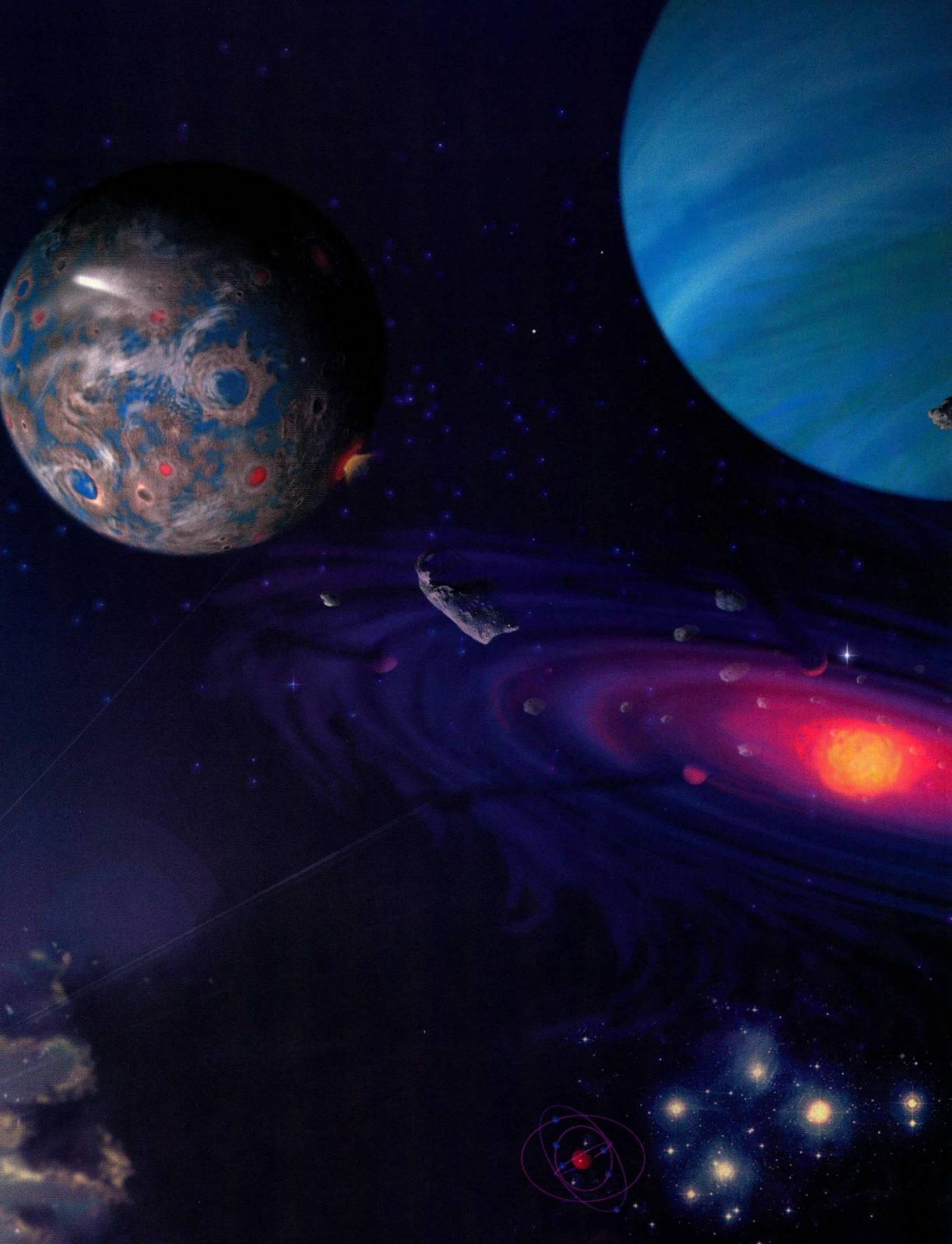
As we approach the dawn of a new century, it's time to reflect upon the accomplishments of the past 100 years / We learned that the Milky Way is just one of billions of galaxies in an ever-expanding universe / Scientists determined how stars are born, how stars shine, and how they die / The entire spectrum was opened up, from radio waves to gamma rays, revealing a universe of unimaginable violence and diversity / Astronomers discovered the first planets orbiting other stars / Our robotic emissaries gave humanity its first close-up look at other worlds / And in perhaps the century's greatest achievement of any kind, human beings set foot on another world / These accomplishments transformed our perception of our world, our universe, and even ourselves / But our inquisitive spirit remains unchecked / Advancing technology guarantees that an even greater transformation awaits us in the 21st century / In this special issue, *Astronomy* gives you a sneak preview of the century to come — a century when humans will likely discover life-bearing planets around other stars, answer the ultimate questions about the origins of the universe, galaxies, and life, and take the first tentative steps to establish a multi-world civilization / As exciting as 20th-century astronomy and space exploration have been, the best is yet to come / *Robert Naeye*





Looking for Life

Space observatories of the future will be capable of spotting life-bearing planets in the glare of nearby stars.

by Robert Naeye

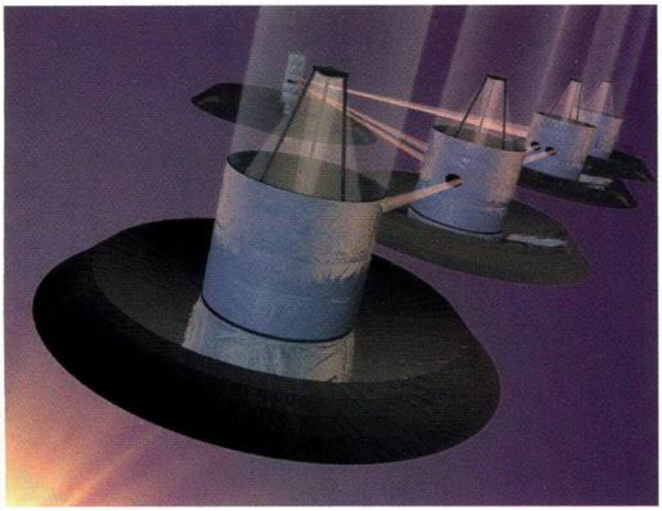
Fast-forward in your imagination to the year 2012. A squadron of four free-flying telescopes orbiting the sun a million miles from Earth swivel and aim on cue. The target of their 3.5-meter mirrors is 12 light-years away; the sunlike star Tau Ceti. Sophisticated optics and electronics cancel out the star's glare, allowing three nearby specks of light to slowly emerge on computer screens back on Earth. These tiny dots herald one of the greatest scientific discoveries of all time — the first Earth-sized planets directly observed beyond our solar system.

After this array of space telescopes, known as Terrestrial Planet Finder (TPF), tracks the planets' orbital motions for several months, an international team of astronomers is delighted to learn that the middle planet orbits Tau Ceti at roughly the Earth-sun distance.

The astronomers then command TPF to gather light from the planet for two weeks to obtain a spectrum. Just as a picture is worth a thousand words, the spectrum is worth a thousand pictures — or perhaps more. It reveals the presence of water vapor, carbon dioxide, and oxygen — a combination of gases that is the chemical signature of life as we know it. Centuries of speculation turned out to be right; Earth is not the only life-bearing planet in the cosmos. Welcome to space astronomy in the 21st century.

Next century, astronomers will focus on the origins of everything.

NASA, JPL, Caltech, Pat Rawlings



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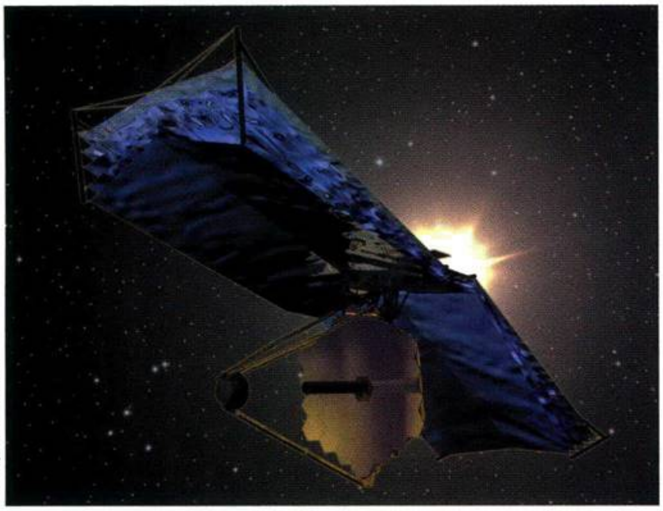

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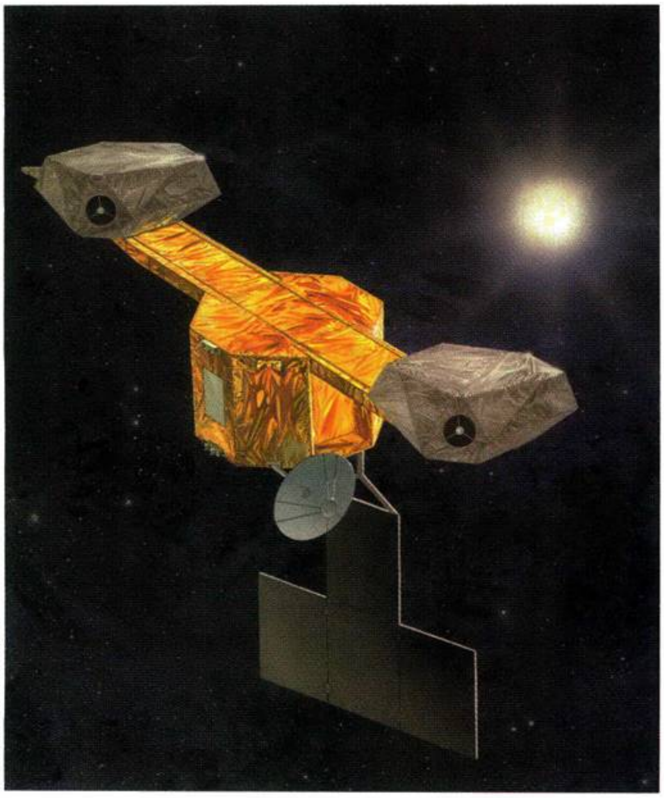


Craig Attebery, JPL, Caltech

The Challenge

NASA's Office of Space Science has combined several ongoing and future missions into a program appropriately named Origins. If funded by Congress as planned, Origins could provide answers to two questions humans have pondered for millennia: Where do we come from, and are we alone in the cosmos? One program goal is to identify life-bearing planets orbiting nearby stars. "The laws of physics say we can do it," says TPF project scientist Charles Beichman of the Jet Propulsion Laboratory. "It's just a matter of having the will and spending the money on the technology."

Ground-based telescopes are expected to make amazing discoveries in the next century (see "Giant Eyes on the Sky," page 48), but space is the place to be if one is looking for life. That's because Earth's atmosphere absorbs most infrared light — the spectral region where extrasolar planets will be easiest to see and where the spectral signature of life shows up most clearly.

But even with telescopes perched above the atmosphere, astronomers face a daunting task. An extrasolar Earth would be dim compared to the parent star, like a firefly hovering near a bright searchlight. Astronomers must develop large mirrors to gather enough light to see such planets. They also need space interferometers — arrays of telescopes spread far apart to achieve high resolution (see "The Power of Numbers," page 50). Interferometers must also be configured to combine the crests and troughs of incoming light waves to cancel out (or "null") the glare of the star to reveal planets.

The Birth of Galaxies

The Next Generation Space Telescope (NGST) will address the challenge of big mirrors in space. Two competing contractors are developing designs for the telescope; both call for segmented mirrors about 8 meters in diameter.

With its large mirror and super-sensitive infrared detectors, NGST will see farther back in space and time than the Hubble Space Telescope. NGST will see the first galaxies assembling a few hundred million years after the Big Bang (see "When Galaxies Were Young," May 1998). The telescope also will peer into interstellar gas clouds where stars and planets are born. "The purpose of NGST is to see how it all started, how we got here," says NGST project scientist John Mather of NASA's Goddard Space Flight Center.

To conform to NASA administrator Dan Goldin's mantra of "faster, better, cheaper," managers of each Origins mission will streamline their projects and use smaller teams of scientists and engineers. NASA also is spending more money on cutting-edge technologies now in order to reduce costs later.

For example, while NGST's 8-meter mirror will dwarf Hubble's 2.4-meter mirror, NGST will cost only $500 million — about one-fourth the construction cost of Hubble. NGST will herald a new generation of "gossamer optics" — mirrors made of lightweight yet sturdy materials. NGST's mirror will weigh one-tenth as much per square meter as Hubble's. Such mirrors, folded up before launch, will unfurl in space like petals of a flower.

"We want to increase the science per dollar just at the time when the dollars appear to be decreasing," says acting Origins Theme director Harley Thronson. "The Origins

Terrestrial Planet Finder, top, the Next Generation Space Telescope, middle, and the Space Interferometry Mission, bottom, form a trident of early-21st-century space telescopes that will explore cosmic origins.

program brought several missions together and connected them in a strategic plan that allows the technology of one spacecraft to build on the preceding ones."

Looking for Life

Astronomers will develop the interferometry technology needed for TPF on two missions — Space Technology-3 (ST-3) and the Space Interferometry Mission (SIM). ST-3, scheduled for launch in 2005, will test formation flying with two small, free-flying telescopes (see "Unveiling Tomorrow's Technology," page 56). The spacecraft will maintain a 0.6-mile (1-km) separation to within 0.00004 inch (1 micrometer) by using sophisticated laser ranging, thrusters, and onboard controls. This precision is required for TPF.

While SIM's design has not been finalized, it might consist of two 12-inch (30-cm) telescopes mounted on a truss 30 to 50 feet (10 to 15 m) long. SIM, which could be launched in 2005, will demonstrate nulling interferometry in space with precise optics and computers (see "Nulling a Star," January 1999). SIM will pinpoint stellar positions so precisely that it will detect "wobbles" induced by planets only a few times more massive than Earth. SIM also will measure distances to objects anywhere in our galaxy to within 10-percent accuracy.

By incorporating the technologies of NGST, ST-3, and SIM, NASA could launch TPF as early as 2011. The European Space Agency (ESA) is working on its own version of TPF called Darwin. Interestingly, NASA and ESA appear to be converging on a similar design. They may launch a single mission that would be capable of finding terrestrial planets orbiting some 200 stars within 50 light-years of Earth.

Spectra could reveal atmospheric water vapor, carbon dioxide (a possible by-product of animal life), and oxygen (see "Wanted: Life-Bearing Planets," April 1998). Forms of pure oxygen in the atmosphere would virtually clinch the case for life because oxygen combines readily with other elements and would quickly disappear unless it were continually replenished via biological processes.

Oceans and Continents

If astronomers find life-bearing planets around Tau Ceti or other stars, what will they do for an encore? Carnegie Observatories astronomer Alan Dressler, who helped inspire the Origins program, notes that the Origins won't stop with TPF. "If you're really ambitious and want to learn details about these worlds from here," he says, "it will require huge telescopes that will make NGST look like a baby."

A scaled-up version of TPF called Life Finder, consisting of perhaps six to ten 25-meter telescopes, would obtain high-resolution spectra of these distant worlds. "TPF will detect the major constituents of a planet's atmosphere," says Beichman. "But the questions of life will be subtle enough that you're going to want to go to the next level of data to find less ambiguous tracers of life."

Beyond Life Finder is Planet Imager, an armada of roughly a hundred 10-meter telescopes spanning hundreds of miles. Planet Imager would fulfill Goldin's dream of imaging oceans and continents on a twin Earth (see "Dan Goldin's Vision," page 64). But while astronomers know what is required to make Planet Imager, its sophisticated technology and exorbitant cost guarantee that Goldin's dream will remain just that — at least until the mid-21st century.

Besides looking for life, TPF, Life Finder, and Planet Imager could watch gas swirl into black holes and resolve sunspots on the surfaces of other stars. And long before Planet Imager is built, astronomers will probably launch space interferometers to observe x rays, microwaves, radio waves, and even gravitational waves. Astronomers may someday set up giant radio telescopes on the farside of the moon, which is shielded from human radio transmissions.

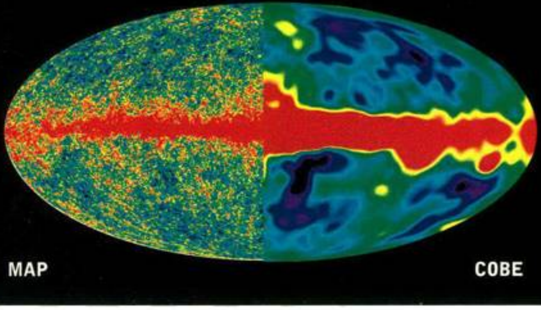
All this is going to cost lots of money. But who can put a price on knowledge? "The dawn of the 21st century is going to be a period of time when very important long-standing questions about the origins of life will finally be answered," says Thronson. "It's a time I wouldn't want to miss for the world." John Mather adds, "When we accomplish all this, we will change the way we look at ourselves." ■

Associate editor Robert Naeye is writing a book for junior high school students about the Chandra X-ray Observatory.

MAPping the Universe

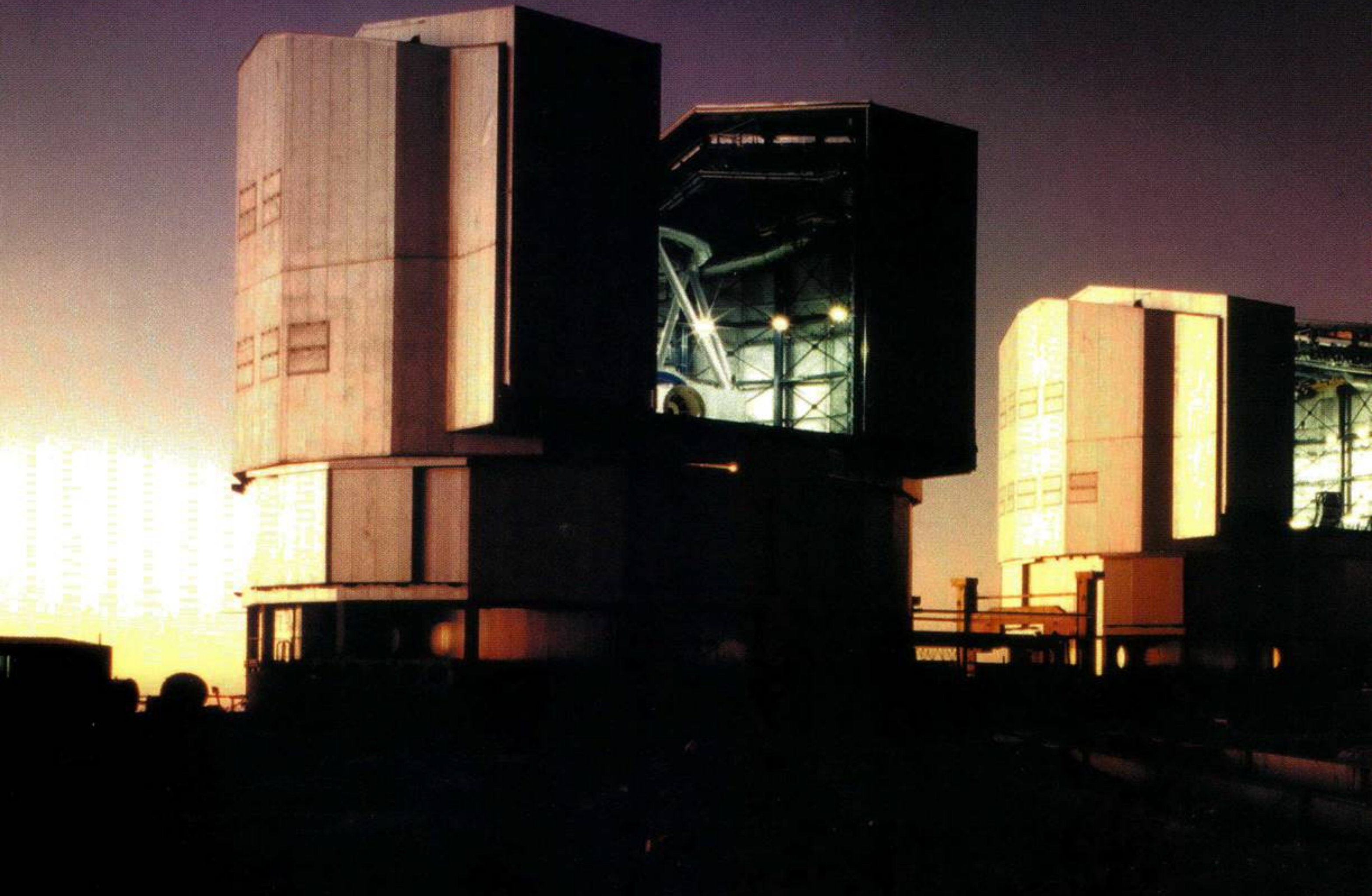
The Origins Program isn't NASA's only space-astronomy program. NASA's Explorers Program develops small, inexpensive spacecraft that can focus on specific scientific problems. In November 2000, NASA will launch the $80-million Microwave Anisotropy Project (MAP) spacecraft. It will create a fine-scale map of temperature variations in the cosmic microwave background, the afterglow of the Big Bang. MAP will be able to see temperature variations across much smaller patches of sky than those seen by the COBE satellite of the early 1990s (see illustration below).

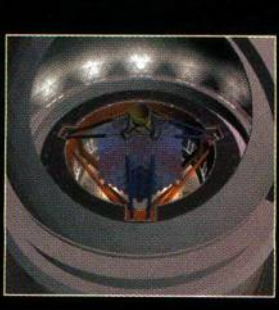
"If the satellite works the way we hope and if the universe cooperates, we'll be able to answer a whole set of the key questions that have been driving cosmology for the last couple of decades," says Princeton University astronomer David Spergel of the MAP science team. These questions include the expansion rate and matter density of the universe and the origin of primordial density fluctuations that gave rise to clusters of galaxies. — *R. N.*



Images: NASA

Giant Eyes on the





Sky

They're not just overwhelming, they're outraged. Ground-based telescopes of the 21st century will dwarf their modern-day counterparts.

by Govert Schilling

Imagine a mirror the size of a basketball court — a vast expanse of glass, more than 30 meters in diameter, weighing some 150 tons and consisting of more than 250 hexagonal segments of two meters each. Got it? Okay, you're looking at the secondary mirror of next century's super telescope. That's right, the *secondary*. The primary, matching the size of a football field, lies 100 meters below, near the base of a telescope structure as high as the Great Pyramid. Welcome to the 100-meter OWL, or OverWhelmingly Large Telescope, which has 10 times the collecting area of all existing professional telescopes put together.

OWL is neither a dream nor a fantasy. It's a serious plan currently under study at the European Southern Observatory (ESO). Optical engineers have already finalized the blueprints for the mirrors, and ESO's technicians are designing a Tinkertoy-like mechanical structure consisting of some 4,000 pipes, each with a diameter of two meters.

Roberto Gilmozzi of ESO, OWL's project manager, believes the job can be done for $900 million. "We're aiming for a highly modular design, and we're just using the technologies that are available today," he says. If funded, sometime around 2012 OWL could see technical first light, meaning that at least some of the 2,000 mirror segments that will make up the 100-meter primary are in place. "In 2015, limited science observations could commence," says Gilmozzi, "and around 2018, the telescope could be fully commissioned."

OWL would dwarf all existing telescopes, including the combined four 8.2-meter unit telescopes that will make up ESO's ambitious Very Large Telescope (VLT), currently under construction in northern Chile (see "King of the Mountain," March 1999). Aided by state-of-the-art cameras and spectrometers, OWL's awesome light-gathering power would reach down to 38th magnitude, and thanks to adaptive optics (see "De-blurring the Sky," page 51), it would see details as small as 1.4 milliarcseconds (the width of a penny seen at 1,700 miles). "With OWL, we will resolve sunlike stars in the Virgo cluster of galaxies," says Gilmozzi, "as well as individual star-forming regions in the very distant universe." Faint white dwarfs would be observable all the way out to the Andromeda Galaxy, and Jupiter-like planets 30 light-years away could be detected in a matter of seconds.

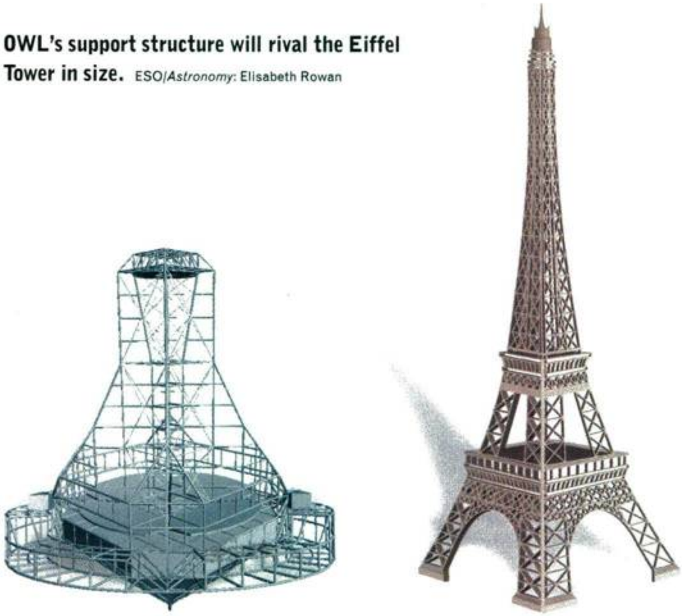
Main image: The Very Large Telescope under construction. ESO **Inset Left: An artist's conception of a 50-meter "Giant Optical Device."** Jon Lomberg/NOAO **Inset Center: A design for a 50-meter telescope in Sweden.** Lund University **Inset Right: The 35-meter Extremely Large Telescope would have a fixed altitude.** VIZIX Inc./NOAO

As you've probably guessed, building a 100-meter telescope is no small task. OWL's mechanical structure, weighing a horrendous 20,000 tons, will look like a mesh of metal rods — more akin to the Eiffel Tower than to a traditional telescope tube. During the day, four petal-like air conditioned covers will slide over the four quadrants of the main mirror to keep it at nighttime temperature, and, if necessary, an arena-sized hangar will roll over the telescope to protect it against the elements.

Unlike the segmented 10-meter parabolic mirrors of the twin Keck telescopes on Mauna Kea, Hawaii, OWL's primary mirror, which will weigh more than 1,500 tons, will have a spherical curvature so that its 2,000 segments will be identical. Mass-producing the 2.3-meter mirror segments would take eight years at a rate of one segment per work day. According to ESO optical engineer Philippe Dierickx, the huge segmented secondary mirror will be flat, and a complex corrector mirror unit, about as large as an entire VLT unit telescope, is necessary to compensate for the image distortions introduced by the spherical primary.

OWL is by far the most ambitious proposal for a 21st-century monster optical telescope. But it's not the only one. All over the world, astronomers and engineers are studying novel designs for ground-based telescopes with primary mirrors measuring between 20 and 50 meters across. Called Giant Optical Devices (GODs) by Jerry Nelson, designer of the Keck Observatory's segmented mirrors, these behemoths would combine ultrasharp vision with mind-boggling sensitivity, making them the instrument of choice for studies of extremely distant galaxies at the dawn of time and detailed observations of the dusty cradles of stars and planets.

OWL's support structure will rival the Eiffel Tower in size. ESO/*Astronomy*: Elisabeth Rowan



At Lund University in Sweden, Arne Ardeberg and Torben Andersen have developed plans for a 50-meter Extremely Large Telescope (XLT) with a 585-segment parabolic primary and a tiny secondary of "only" four meters. "We also considered a monolithic primary, as well as a mirror consisting of 100,000 15-centimeter segments," says Andersen. "However, the Keck design is a proven concept, and it's easier to convince funding authorities that it actually will work."

In the United States, Thomas Sebring and his colleagues from the National Optical Astronomy Observatories

The Power of Numbers

Interferometry enables two or more telescopes separated by, say, 100 meters, to see as sharp as one giant 100-meter telescope would. How does it work? Actually, the concept is quite simple. Suppose you built a 100-meter parabolic mirror, which would have an exquisite angular resolution of 1.4 milliarcseconds. All light waves collected by this mirror will end up at the telescope's focus "in phase," meaning that the crests and troughs of the individual light waves are all lined up, which is necessary to obtain high angular resolution.

Now suppose you painted the mirror black, except for two 10-meter circular patches on opposite sides. The resulting telescope would be much less sensitive because only a small part of the mirror would be able to reflect light. But it would still have the same resolving power as the full 100-meter telescope because the light waves that end up in the focus are still in phase. So if you could build two 10-meter telescopes (separated by 100 meters) in such a way that their mirrors are part of the same virtual 100-meter parabolic surface, you would end up with an instrument that has the same resolving power as a 100-meter telescope (but with much reduced sensitivity).

W. M. Keck Observatory

Astronomers are developing interferometry for some of the largest ground-based telescopes in the world, including the two 10-meter Keck telescopes on Mauna Kea (left). These telescopes are separated by about 100 meters and are of course not part of the same parabolic surface. So the individual light waves from different parts of the two mirrors will not be in phase when they are brought to a common detector. For interferometry to work, astronomers will have to make a lot of corrections to compensate for the fact that the light rays from each telescope are traveling different path lengths.

These corrections are much harder to do for infrared and optical wavelengths than for longer radio wavelengths: The mutual positions of the two mirrors have to be known with an accuracy comparable to the wavelength — meters for radio waves, micrometers for visible light. That's why interferometry has been a household word in radio astronomy for decades while optical interferometry is still in its infancy. But with the rapid pace of technical innovation, both the Keck Interferometer and the Very Large Telescope Interferometer should be fully operational around 2001.

De-blurring the Sky

Astronomers would like to get rid of the blurring effects of the atmosphere. Adaptive optics compensate for air turbulence by using a small, deformable mirror in the light path. Small actuators vibrate this mirror, which "de-blurs" the light from a distant cosmic source. Exactly how the mirror has to be flexed is determined from measurements of the distorted image of a guide star, which tells a computer how the atmosphere is distorting the image. The guide star can either be a natural star in the telescope's field of view or an artificial one, created at an altitude of some 50 miles (80 kilometers) by a laser beam.

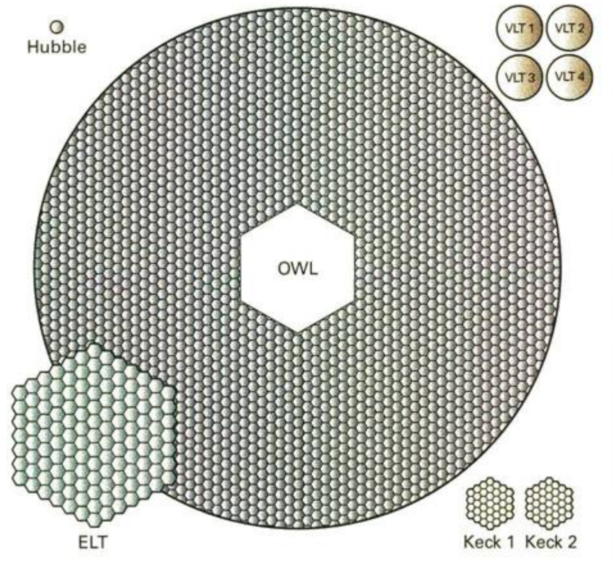
Adaptive optics will soon become a standard feature of ground-based telescopes, and tests have shown that such telescopes equipped with adaptive optics can take sharper pictures than the Hubble Space Telescope at some wavelengths. But the technique is not advanced enough yet for 50- or 100-meter telescopes, which would see through such a wide column of air that several guide stars will be needed.

Air Force Research Laboratory / Starfire Optical Range

(NOAO) also try to "play it safe." They have proposed a 35-meter ELT (Extremely Large Telescope) based on the design of the Hobby-Eberly Telescope at McDonald Observatory in Texas. Hobby-Eberly has an 11-meter mirror, but because it has a fixed altitude, a maximum of 9.2 meters' worth of mirror can see the sky at a given time. Likewise, ELT's segmented spherical primary mirror will have a fixed elevation with respect to the horizon, rendering about 30 percent of the sky invisible. The simple design, however, would lead to a tremendous cost reduction. "We're talking about a total cost of $250 million," says Sebring, "which is probably a conservative estimate." The total cost of ELT would be about 50 percent more that the combined cost of the two Keck telescopes, but ELT would collect six times more light.

Why build 35-, 50-, or even 100-meter telescopes when optical interferometry can reach the same angular resolution by combining the power of a number of smaller telescopes (see "The Power of Numbers," page 50)? After all, the four telescopes of the VLT will be spread across 130 meters, giving the array the resolution of a single 130-meter telescope — even sharper vision than OWL will have. The answer is twofold. First, interferometers such as the VLT fall far short of the full light-gathering power of a complete 100-meter scope, so they can't see very dim objects (OWL can go as deep as 38th magnitude, about 4 magnitudes fainter than VLT will be able to reach when construction is completed around 2006). Second, when used as an interferometer, the VLT (or the Keck interferometer, for that matter) will have a very tiny field of view, unsuitable for the study of extended objects such as galaxies and star-forming regions.

Telescopes Compared



Astronomy: Elisabeth Rowan

According to veteran telescope designer Ray Wilson of ESO, "The limits on achievable telescope size are no longer obvious. There are no absolutes." Wilson welcomes the wide variety of solutions. "Final decisions will be made on the basis of cost analysis," he says. And thanks to technical innovations, a classic rule of thumb that says doubling a mirror's size increases costs sixfold no longer seems to apply.

One main worry is computer power. To continuously align OWL's 2,000 primary segments, half a million computer-steered actuators are necessary, which will have to act against the deforming powers of wind pressure, gravity, and temperature changes. What's worse, adaptive optics, needed to overcome the blurring effects of the atmosphere, are much more difficult to realize for a 50- or 100-meter telescope than for a 10-meter telescope. "Don't underestimate the complexities of adaptive optics," says Nelson. "This is by far the hardest problem we're faced with."

Despite all these technical hurdles, Gilmozzi and his colleagues are confident that their dreams will be realized in the next 20 years. "We're witnessing the second quantum jump in ground-based astronomy," he says. "Going from the VLT to OWL is as profound a step as going from the naked eye to Galileo's first spyglass." ■

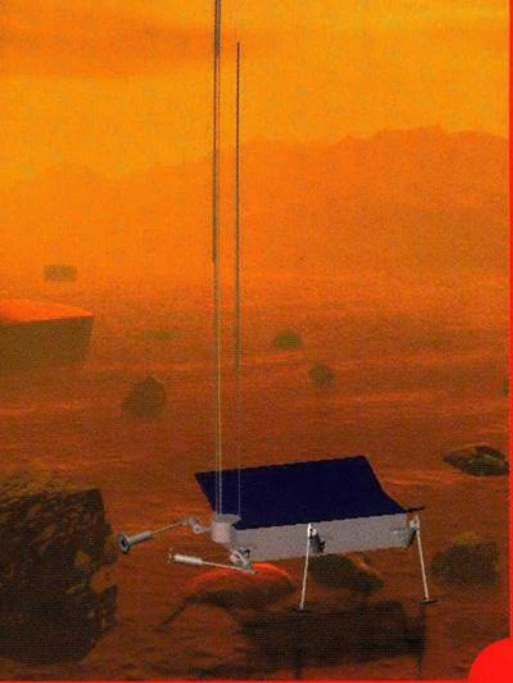
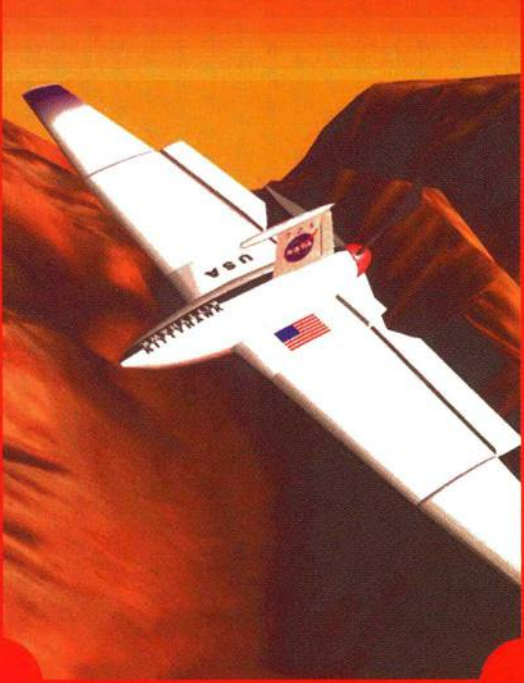
Govert Schilling is an astronomy writer in Utrecht, the Netherlands. His largest telescope has an aperture of 7.5 centimeters (3 inches).

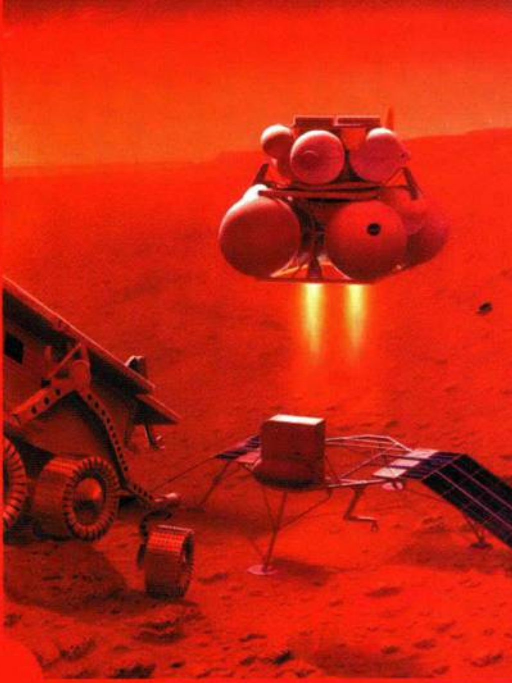
Pursuing the Planets

From a distance, they look like ants in an ant colony — thousands of small creatures scurrying around the martian surface. At closer range, they turn out to be terrier-sized machines, all identical in appearance. Their mission: scientific reconnaissance of the Red Planet, the establishment of communication systems, and construction of the first outpost on Mars. When human explorers finally arrive, there will already be a habitable base for them to occupy.

That's John C. Mankins's vision of planetary exploration for the 21st century. Mankins, the manager of advanced concepts at NASA's Office of Space Flight in Washington, D.C., draws inspiration for his robotic corps from colony life-forms on Earth. "Take ants or bees," he says. "Each one is identical to the others, and yet look at the diverse goals they accomplish with a little bit of coordination." The development of biomimetic systems, machines that mimic life, could be the key to long-term exploration of the solar system and beyond, according to Mankins.

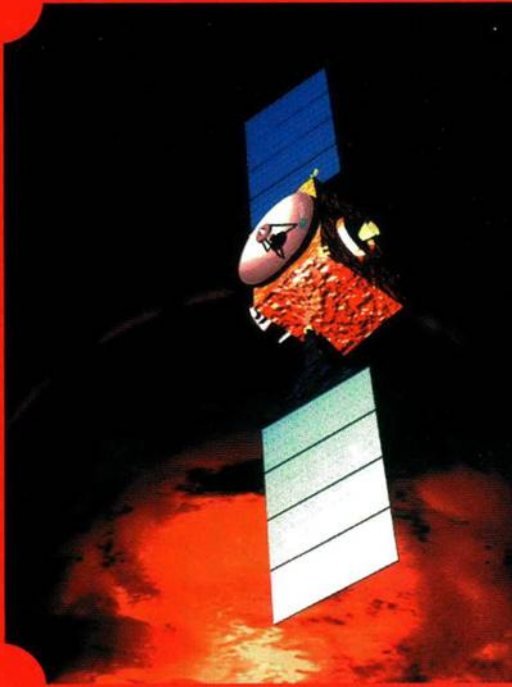
Credits clockwise from upper left: Hexabot on Mars: NASA/JPL; Mars Airplane: Malin Space Science Systems; Mars Sample-Return Mission: Pat Rawlings/NASA/JPL; Mars Express Orbiter: European Space Agency; Mars Sample-Return Mission: NASA/JPL; Mars 2001 Orbiter: NASA/JPL; Mars 2001 Lander and Rover: NASA/JPL; Mars Express Beagle 2 Lander: The Open University/European Space Agency

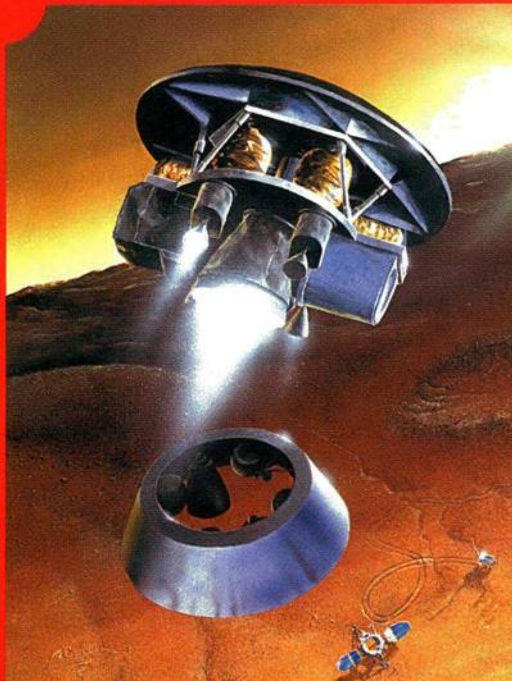





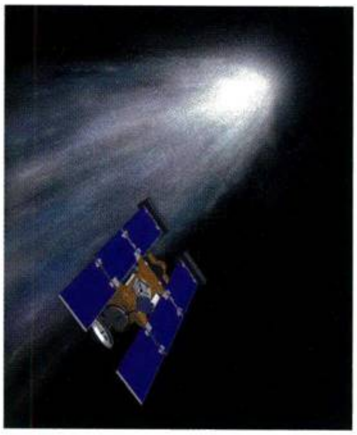
When it comes to planetary exploration, miniature robots could be the wave of the future.

by Ray Jayawardhana





COMET QUEST



Stardust will fly through Comet Wild-2's coma in 2004. NASA/JPL

Comet chasing is becoming quite fashionable. In the next decade, at least three spacecraft are headed for comets. Stardust, which NASA launched in February 1999, will have a close encounter with Comet Wild-2 (pronounced Vilt-2) in January 2004. During its closest approach, Stardust will venture within 60 miles (100 km) of the comet's nucleus and take photographs of its surface. While flying through Wild-2's coma — the gas and dust envelope that surrounds the nucleus — the spacecraft will extend a paddle-shaped collector to capture material spewed out from the comet. The samples will be stored in a capsule that will eventually separate from the rest of the spacecraft and parachute into the Utah desert in 2006.

CONTOUR (Comet Nucleus Tour), a NASA Discovery mission slated for launch in 2002, will study the nuclei of three comets at close range. "The mission design is highly flexible, which lets us keep options open," says principal investigator Joseph Veverka of Cornell University. CONTOUR could even take a detour to visit a bright new comet that has yet to be discovered. The European spacecraft Rosetta, scheduled for a January 2003 launch, will literally chase Comet Wirtanen for two years and attach a probe to its nucleus.

Why is there so much interest in these dirty snowballs? Scientists believe that comets are among the most primitive objects in the solar system and may hold clues to its birth. Comets also contain carbon-rich compounds, which are the basic building blocks of life. As Veverka points out, "Memories of our origins may be stored in the cores of comets." Scientists better look carefully through Stardust's return cargo. — *R.J.*

PLANETARY WISH LIST

A spacecraft hovers a few kilometers above Saturn's magnificent rings. A mission returns soil samples from Venus. An orbiter images Neptune's atmosphere, rings, and moons. That's just a small selection from the planetary scientists' wish list for the new century. These are among the many exciting planetary missions being studied by a panel of experts called upon to advise NASA on future science priorities. "Of course, it all depends on funding levels for NASA," says Carolyn Porco of the University of Arizona.

Porco, who leads one of the working groups within the panel, especially likes the mission to Saturn's rings. "We could make movies of the particles and make laser measurements to get a 3-D picture of the rings," she explains. Such data could provide important insight into the early history of the solar system. Planets, astronomers believe, assemble from small dust particles in a disk around newborn stars. "Saturn's ring system is a great natural laboratory to better understand that process," adds Porco. — *R.J.*

THE OUTER REALM

Europa Orbiter's laser altimeter could find evidence for an ocean of liquid water beneath Europa's icy surface. NASA/JPL

Mars may be the focus of NASA's attention, but the agency hasn't forgotten the outer solar system. The $3.5-billion Cassini spacecraft will rendezvous with Saturn in 2004 and release the European lander Huygens into Titan's upper atmosphere.

If Congress maintains funding, NASA could launch an orbiter to Jupiter's enigmatic moon Europa in 2003. By measuring Europa's shape to extremely high precision with a laser altimeter, Europa Orbiter could detect tidal bulges that would reveal an ocean of liquid water lurking below the moon's icy surface. Next in line could be a lander to examine the composition of ice, to be followed by a "hydrobot" that could melt through the ice and search for life in Europa's murky depths.

NASA also plans to complete its initial reconnaissance of the solar system by flying a mission to the only planet left unexplored by spacecraft, Pluto. If funded, Pluto-Kuiper Express could launch in December 2004. After picking up speed at Jupiter in 2006, the spacecraft will zoom by Pluto and its moon, Charon, in 2012. The spacecraft will continue onward through the Kuiper Belt, where it would possibly encounter one or more of that region's small, icy bodies.

NASA is looking even further afield to the Interstellar Probe mission, which could launch as soon as 2010. Using chemical rockets and a large solar sail to accelerate to 15 astronomical units (AU) per year (four times faster than Voyager 1), the spacecraft would soar beyond the boundary of the solar wind's influence at roughly 100 AU to study interstellar material. — *Robert Naeye*

This mode of exploration has many advantages. First, it's simple: Because each robot can be programmed to perform a multitude of tasks, there will only need to be five to seven basic types (which saves development costs). Second, it's cheap: Once a prototype is developed, it costs little to fabricate legions of copies. Third, many small machines could be linked to form larger machines. Fourth, it's robust: Several robots may malfunction, yet the show would go on. As Mankins points out, "Twenty percent of a beehive can die, yet the colony still survives. The same is true here."

It could be decades before Mankins's robots wander around the Red Planet. But some of the key features of his concept — simplicity, low cost, and robustness — are the hallmarks of a new generation of spacecraft already being built or designed. The missions represent a whole new approach to exploration. The spacecraft are small, high risk, and innovative. But because they are low cost, a single failure won't set back the entire program. Gone are the days of complex, massive planetary spacecraft that required decades to build and giant rockets to launch.

Current plans envision at least 14 spacecraft traveling to Mars by 2010. Some of these missions are small-scale "micromissions" that could include communication satellites, penetrators, balloons, and airplanes. The powerful French Ariane 5 rocket will play a key role in the micromissions. The lightweight micromissions will be secondary payloads, piggybacking into space alongside Earth-orbiting satellites aboard the Ariane 5. Small rockets will then send these spacecraft to the Red Planet.

Mars is the 21st century's destination of choice for two main reasons. First, there is a good possibility that microbial life once existed on the Red Planet. Second, it is the most likely place for a future human presence beyond Earth orbit. "The question of life is a prime driver in martian exploration," explains Charles Elachi, director for space and Earth science programs at the Jet Propulsion Laboratory. Many of the space probes are intended to search for signs of past life and water. They'll also study the geology and climate of Mars as a precursor to human missions.

On December 3, 1999, Mars Polar Lander, along with its pair of Deep Space 2 penetrators (see "Unveiling Tomorrow's Technology," page 56), will start giving us the first detailed views of the edge of the south polar cap. In the meantime, Mars Climate Orbiter will study the atmosphere from above.

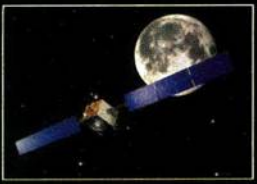
Also on the way to Mars is a Japanese orbiter named Nozomi, which, after an engine failure, was rerouted to arrive at Mars in 2004. Nozomi's primary goal is to study the interaction of the solar wind with Mars's upper atmosphere.

Another NASA orbiter and lander — with a Sojourner-like rover named Marie Curie — will make the journey in 2001. The lander's main job will be to set the stage for future human exploration (see "Settling the Solar System," page 60). From above, the orbiter will map the distribution of elements and minerals across Mars's surface.

ESA plans to launch Mars Express in 2003, which will include both an orbiter with a radar instrument to search for subsurface water and a lander named Beagle 2 to study martian soil. "At a cost to ESA of 150 million Euros ($140 million U.S.), Mars Express is the cheapest Mars mission ever, yet its importance and originality are far greater than the price tag suggests," boasts Roger Bonnet, ESA's science director.

The first of the "micromissions" could be a Mars robotic airplane named Kitty Hawk. If it's funded in time to launch during the 2002 window of opportunity, Kitty Hawk's arrival at Mars on December 17, 2003, would coincide with the 100th anniversary of the Wright Brothers' historic first airplane flight. If NASA doesn't select Kitty Hawk to launch in 2002, it will probably head to Mars two years later during the next launch window.

RETURN TO THE MOON



European Space Agency

"The moon is a test bed for solar-system exploration," declares Mike Duke of NASA's Johnson Space Center. Yet it's the Europeans and Japanese who are now taking the lead in moon missions. Europe plans a high-tech moon orbiter named SMART-1 (above) for launch in 2002. It will carry advanced, new science instruments over the lunar poles and use solar electric propulsion. "We're using this mission to demonstrate technology for future planetary exploration," says Bernard Foing, SMART-1's project scientist.

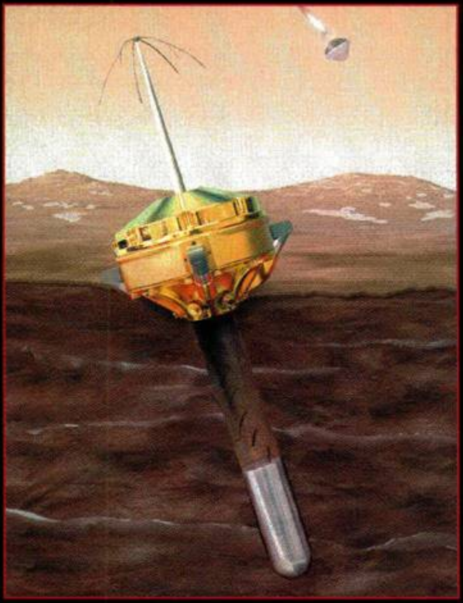
Japan was scheduled to launch Lunar-A, an orbiter carrying two penetrators, in August 1999. But a penetrator failed a drop test, postponing the launch until 2002. A large orbiter and lander called Selene, named after the Greek goddess of the moon, will follow in 2003. — *R.J.*

All these missions are leading up to a return of martian rock and soil samples by 2008. According to the latest plan, sophisticated NASA rovers launched in 2003 and 2005 will collect samples into canisters mounted on simple boosters. Once the canisters reach martian orbit, they will rendezvous with a French orbiter that will bring them to Earth (see "The *Real* Men in Black," July 1999). If successful, more sample-return missions would almost certainly follow.

Will scores of robots head to Mars in the decades to come? Nobody knows for sure. It could depend on the political will of the major nations to commit to a long-term Mars exploration program. Right now, Mankins's dream seems far-fetched. But the first tentative steps toward its realization have already been taken in Neville Marzwell's laboratory at the Jet Propulsion Laboratory in Pasadena, California. Using technology from a variety of sources, Marzwell and his team are developing several types of robots, including six-legged walking machines called "hexabots."

"They're almost smarter than any insect," says Marzwell, who is developing software that will enable a half-dozen hexabots to work together in perfect harmony. "Each one has the full picture of the whole environment, and each one knows what the others are doing," adds Marzwell. Hexabots will measure the composition of rocks, and unlike Pathfinder's rover, Sojourner, they won't need instructions from humans. Someday, maybe within the next decade, hexabots and their brethren will be ready to go where no one — man or machine — has ever gone before.

Contributing editor Ray Jayawardhana studies planet-forming disks from his office at the Harvard-Smithsonian Center for Astrophysics and from telescopes in Hawaii and Chile.



Unveiling Tomorrow's Technology

NASA's New Millennium Program tries out bold new technologies for 21st-century space exploration.

by Ralph Lorenz

Eight minutes before impact on the morning of December 3, 1999, the Red Planet looms large and angry below. Small springs push two basketball-sized probes away from Mars Polar Lander. Like warheads on a ballistic missile, the probes coast on near-parallel courses before plunging into the atmosphere. Wobbling like shuttlecocks, the probes enter nose-first at 14,000 miles (22,500 km) an hour. Frictional heating cooks them with the heat of a thousand suns. The final two minutes are a relatively gentle supersonic plunge before they smash into the Martian surface near the south pole at 450 miles (725 km) an hour. Their entry shields shatter at impact. The impact splits each probe in two. A bullet-shaped forebody penetrates up to 3 feet (1 meter) deep. A flexible cable connects the forebody with a cantaloupe-sized aftbody, which remains at the surface to radio data to the orbiting Mars Global Surveyor. Despite the probes' violent arrival, suffering decelerations of up to 80,000 G's, they begin a set of experiments to search for water ice. Not bad for space probes you could hold in one hand! This innovative mission, called Deep Space 2, is the second in NASA's New Millennium Program (NMP), which explores new, low-cost ways of doing space missions and novel techniques previously viewed as too risky. With headquarters at the Jet Propulsion Laboratory (JPL) in Pasadena, California, the NMP develops space technology for astronomy, along with interplanetary and Earth observing missions.

After crash-landing on Mars at speeds exceeding 400 miles an hour, the twin Deep Space 2 probes will penetrate 3 feet deep. Their main science objective: look for water ice. NASA/JPL

Ion Engine

The New Millennium Program got off to a flying start when Deep Space 1 blasted off on October 24, 1998. This mission's goal is to demonstrate new, lightweight technologies for advanced planetary missions. While the spacecraft employs a total of a dozen new technologies, the ion thruster is perhaps the most revolutionary.

The ion thruster uses electricity to accelerate charged xenon atoms to speeds of 30 miles (50 km) per second. In contrast, the best chemical thrusters burn hydrogen and oxygen to make water vapor and then shoot the water out of a nozzle at 3 miles per second. The faster the gas is shot out of the thruster, the less fuel is needed to push the spacecraft a given amount. A spacecraft powered by an ion thruster can therefore reach its destination with only one-tenth the fuel of a chemical rocket. This kind of lean propulsion is essential for difficult future missions such as a Neptune orbiter.

Soon after launch, Deep Space 1's ion thruster shut down several times when particles of debris shorted out the high-voltage grids that accelerate the gas. "These problems were embarrassing, but their quick resolution led to more robust methods for future ion propulsion systems," says NMP chief scientist Dave Crisp of JPL. "The ion thruster has performed flawlessly ever since and has met all its performance goals."

Another trick being tested on this mission is autonomous navigation — having the spacecraft work out for itself where it is rather than having an expensive crew of people do it on the ground. Onboard computers calculate the position of the spacecraft in the solar system by taking images that show the planets relative to the stars.

Even though doing science wasn't Deep Space 1's primary objective, the spacecraft made a successful flyby of asteroid 9969 Braille on July 29, 1999. Because the oblong asteroid was only 1.5 miles (2.5 km) long, the automatic pointing programs on board failed to lock onto it until the last moment, so only a few low-resolution images were obtained. But spectroscopic data have revealed, surprisingly, that Braille seems to be chemically similar to the large asteroid Vesta and may even be a chip off the old block. At a distance of less than 16 miles (26 km), this was by far the closest-ever asteroid flyby, and the experience with the autonomous pointing will be invaluable for future missions.

If NASA program managers can find the money, Deep Space 1 may fly past two comets in 2001. The mission has cost taxpayers only $152 million — 50 percent cheaper than any other mission to fly by an asteroid so far.

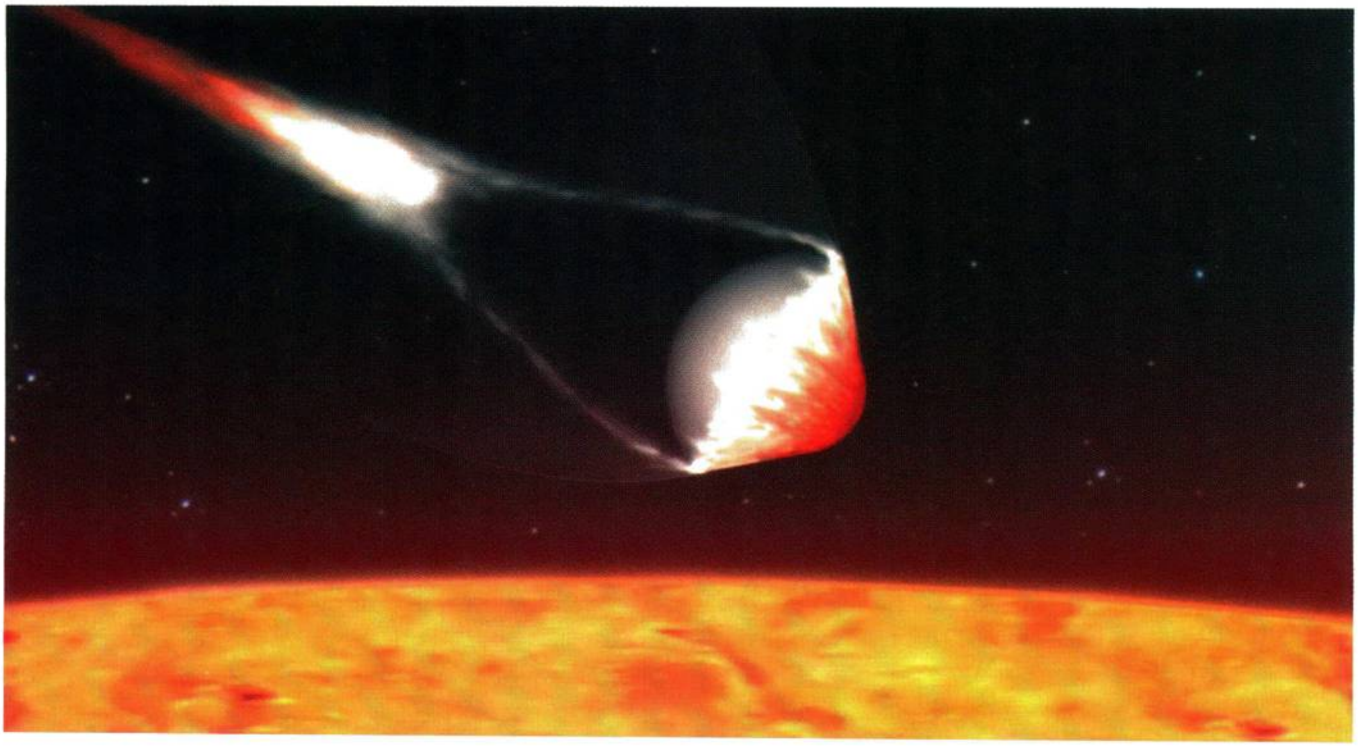
Crashing Mars's Party

While most spacecraft are delicate, spidery structures adapted to the weightless vacuum of space, the Deep Space 2 penetrators are as dense and hard as cannonballs. The two penetrators will slam into Mars on December 3 at 76° south latitude, just a few hundred miles from the ice cap. Pictures from orbit show alternating layers of dusty and presumably ice-rich material at these latitudes.

The Deep Space 2 microprobes carry instrumentation that will complement the more sensitive measurements to be made 30 to 60 miles (50 to 100 km) farther south by Mars Polar Lander (see "Divining on Mars," February 1999). An accelerometer on each microprobe measures the force of the impact and will determine how deep the penetrator is buried. The microprobes will use a small drill to bring in samples of material. The samples will be dropped into a pea-sized heater cup. If ice is present, the heater will need additional electrical power to heat the sample as compared to a sample of pure dirt. A laser spectrometer the size of a soda-can ring opener will also detect water vapor given off by ice.

The tiny microprobes should survive at least a day before their batteries run out. Scientists will monitor how fast they cool as their temperatures plummet to –110° F (–80° C) in the frigid martian soil. The cooling rate will tell scientists the

The Deep Space 2 microprobes will separate from Mars Polar Lander and enter the martian atmosphere at 14,000 miles an hour. NASA/JPL



insulating properties of the soil that controls how deep and for how long ice takes to evaporate.

Penetrators have never been tested on any planet other than Earth, but project manager Sarah Gavit of JPL expresses optimism: "We have developed techniques for allowing electronics to survive the high-G impacts. So if the probes land in a reasonable terrain, and if it isn't a very windy day on Mars, we're pretty confident that the probes will work." Each component has been exhaustively checked out in a two-year program of tests in New Mexico, which included blasting test probes into the ground with a large air gun.

A sign in the project office proclaims, "We don't need no stinking airbags." That's because landers robust enough to survive an 80,000-G jolt don't need airbags or retrorockets to cushion the landing. Without these heavy and expensive systems, probes can be made so small that a mother ship could distribute them in large numbers around a planet's surface. The entire Deep Space 2 mission costs a mere $29.7 million.

If the microprobes work, they will open the way for seismic networks to probe the internal structure of planets, satellites, and asteroids. Burying a probe is the easiest way to maximize its sensitivity to seismic motion while eliminating the wind vibration that ruined the Viking landers' seismic experiments. Other microprobe networks could carry weather sensors to study atmospheric circulation of Venus and Mars. "Network science will allow us to take the pulse of another planet and determine just how dynamic it is," says Sue Smrekar of JPL, the Deep Space 2 project scientist.

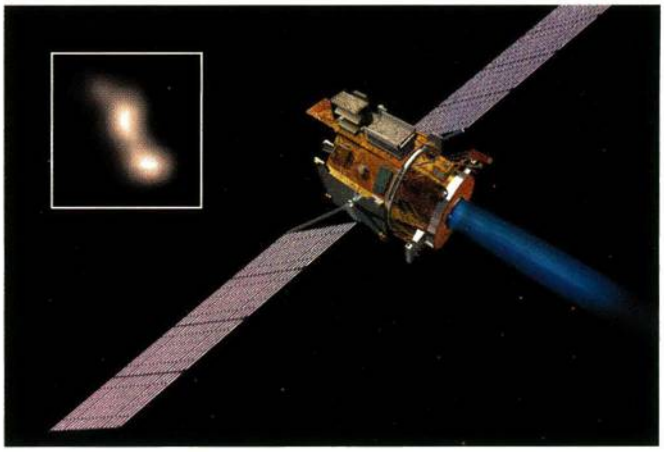
Free-Flyers

As if these ambitious planetary missions weren't enough, the New Millennium Program is stepping up to NASA's challenge of observing planets around other stars. Astronomers still can't image such planets, instead they detect the heaviest planets indirectly. The difficulty in imaging planets is that a planet's faint glow is lost in the glare of its parent star.

Astronomers need telescopes with exceptionally high resolving power to see Earth-sized planets and take spectra to look for life-signaling gases such as oxygen and water vapor. Normally, high resolving power would mean space telescopes with mirrors hundreds of meters across, an expensive and difficult proposition. The solution relies on a technique called interferometry, which combines the light from several telescopes to make the whole greater than the sum of the parts (see "The Power of Numbers," page 50). Astronomers can construct an array of small telescopes that has a resolving power as good as a mirror as wide as the separation distance between the telescopes. If high resolution is your goal, an array of 0.5-meter mirrors spaced 100 meters apart is much easier to build than a single 100-meter mirror.

This technique — used for decades on radio telescopes — relies on very precise knowledge of the distance between the detectors, with precision related to the wavelength of light being studied. That precision is centimeters for radio telescopes but mere microns for optical telescopes. One could maintain constant distance between telescopes by mounting two or more optical telescopes on a metal truss, but this makes the whole array heavier and more expensive to launch.

A smarter approach is to dispense with the truss and use free-flying spacecraft. If fully funded, NMP's Space Technology 3 (ST-3) interferometry mission will demonstrate how free-flying spacecraft can maintain perfect formation using lasers, computers, and microthrusters. In 2003, two telescope-bearing spacecraft will be launched bolted together. Several days after launch, they will be released to fly separately. The separation distance between the spacecraft — up to 1 kilometer — will be carefully controlled to within a few centimeters. Actuators on board will move the mirrors over this range with a submicron accuracy to properly combine the light from the two telescopes. If the distance can be controlled and the two telescopes pointed accurately, the mission will pave the way for Terrestrial Planet Finder, a space interferometer that will look for signs of life on Earthlike planets orbiting other stars (see "Looking for Life," page 44).



Besides testing 12 new technologies, Deep Space 1 imaged asteroid Braille (inset). It might fly by two comets in 2001. NASA/JPL

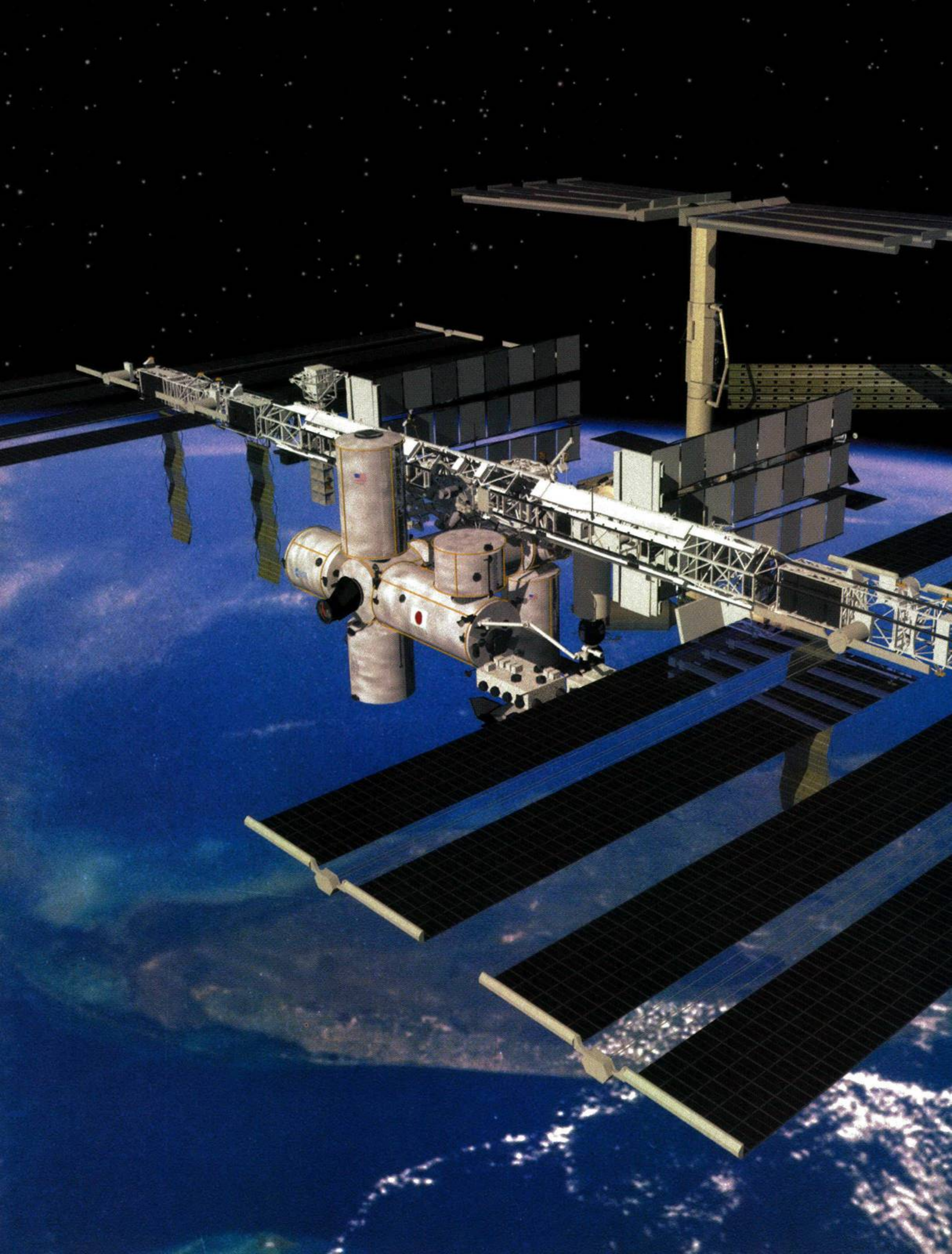
While ST-3 is almost exclusively a technology demonstrator mission, ST-3 project scientist Mike Shao of JPL is particularly excited about obtaining science data on Wolf-Rayet stars, which are hot, massive, powerful stars that boast outflows of gas thousands of times stronger than our own solar wind. "We know basically nothing about these winds," says Shao, "but ST-3 may be able to tell whether the gas is focused into jets or sprays out uniformly."

The High Frontier

Pushing back the frontiers of space technology has risks, so the New Millennium Program is an easy target for budget cutters. ST-4, also called Champollion, would have landed an instrument package on Comet Tempel 1 in 2005. Even though the mission was on schedule and within budget, it was canceled earlier this year in order to cover cost overruns in other NASA programs. But in August, NASA selected a new $28-million NMP mission consisting of three birthday cake-sized satellites that will test eight technologies for space and Earth science missions. This Nanosat Constellation Trailblazer mission is scheduled to launch in 2003.

While NASA missions are usually associated with scientific discovery, the NMP's pioneering endeavors can perhaps be more appropriately compared to the achievements of the Wright brothers. They didn't design a particularly remarkable airplane, or even discover profound new principles of aerodynamics. But they showed you could fly. Once that was done, all kinds of future miracles became possible. ■

University of Arizona planetary scientist Ralph Lorenz works on the Deep Space 2 science team. He has written several articles for Spaceflight *and* New Scientist *magazines.*



Settling the Solar System

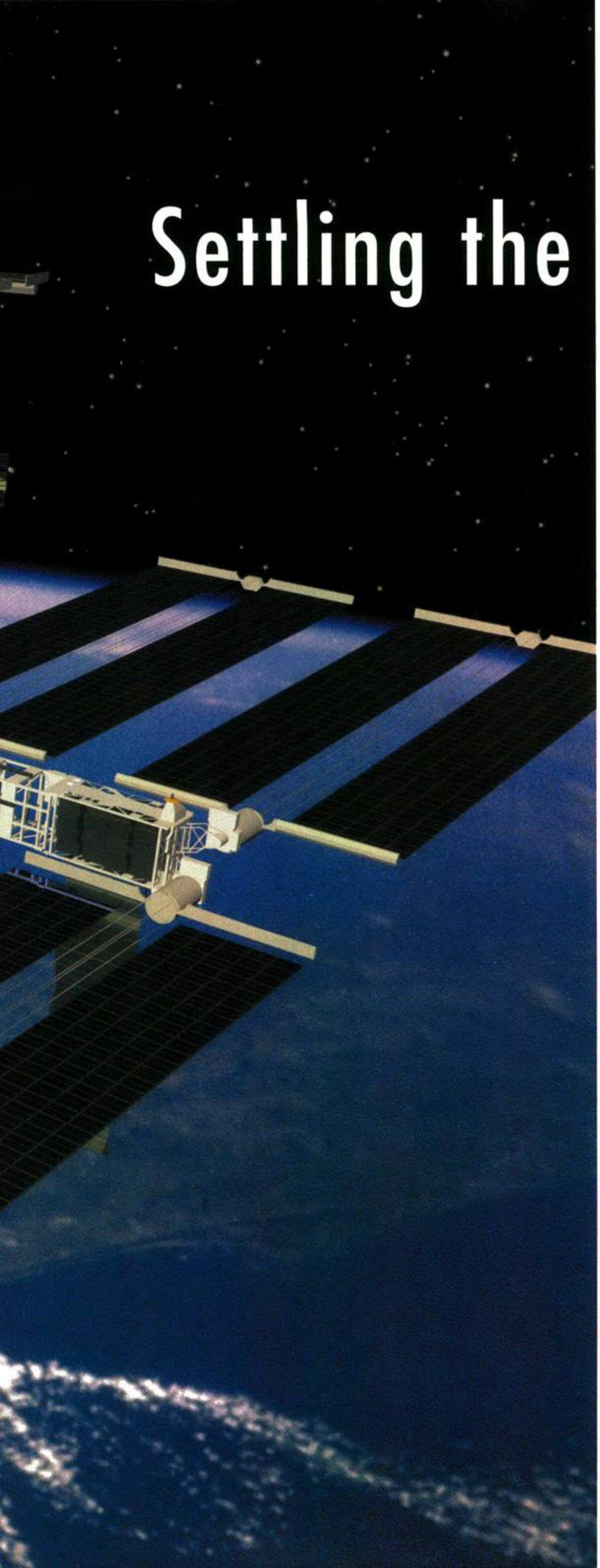
NASA is poised to send a new generation of pioneers into the realm of the moon and planets.

by Aries Keck

It's a frustration felt by everyone from astronauts to kindergartners. We're still here. While NASA takes great strides in sending satellites, probes, and rovers across the solar system, there hasn't been a human footprint on another world since 1972.

But that might change, and soon. Construction of the International Space Station is under way. The success of a little rover called Sojourner has started a groundswell of support for a human colony on Mars. And some even want to return to the moon.

For the first time in 30 years, NASA is seriously thinking about sending humans beyond the familiar confines of low-Earth orbit. "We've just started to take the first baby steps," says John Connolly of NASA's Johnson Space Center. Connolly is in charge of NASA's human exploration initiatives, which he calls the human side of NASA. "The truth is that for the past 27 years, we've been circling Earth in space shuttles and space stations. But we haven't really gotten out of Earth's gravity well."



The International Space Station (ISS), when completed, will be a test bed for the effects of long-term spaceflight.

NASA, Johnson Space Center

Tourists in Space

What might it take to get us out of that well in the 21st century? In a word: tourism.

A study done by NASA and the private Space Transportation Association found that people already spend nearly $1 billion a year on space tourism. But all this money was spent right here on Earth — in museums, space camps, government research centers, and even rocket-launch recovery sites. Add to that the report's discovery that one-third of all U.S. adults would like to spend two weeks in space and most would spend nearly $5,000 on such a trip, and you've got yourself a market.

Two private firms are already taking reservations at $50,000 a pop for space tourism flights. NASA and Lockheed Martin are developing the X-33, a prototype for a fully reusable space airplane that could carry people into orbit for much lower cost than the Space Shuttle. One possible destination would be the International Space Station (see "Outward into Space," December 1998). Now being assembled in low-Earth orbit, NASA has talked of privatizing some parts of the station after its initial 10-year run of collecting scientific data.

But another possibility is the moon. Apollo 11 moonwalker Edwin "Buzz" Aldrin is one of the most vocal supporters of space tourism. Aldrin has joined forces with the German-based company Space Tours to help promote the idea of sending tourists into space. Speaking at a conference this past summer, Aldrin spoke of sightseeing trips to lunar orbit and donut-shaped hotels in low-Earth orbit that could pay for themselves by customers footing the bill.

But these plans exist only on paper for the most part. Overcoming the dramatic cost of getting out of Earth's gravity well keeps most private operations grounded.

Return to the Moon

Curiosity could also spur humans into space. Unanswered questions concerning the moon, asteroids, and even Mars drive NASA to reconsider its robotic approach. "Humans can do things that robots can't," Connolly says. "They're capable of making spontaneous discoveries. They can see things that robots can't."

The superiority of people over robots in being able to answer these curiosities may be what propels us back to the moon. In a recent analysis of photos taken from lunar orbit by the 1994 Clementine mission, NASA scientists have found three areas of prime real estate for future moon bases. The sites are near the moon's south pole, so they receive the maximum amount of sunlight. "If you're at the poles, the sun is always grazing the surface," says Paul Spudis of the Lunar and Planetary Institute. "Basically that means that it never gets extremely hot or extremely cold." The near-constant sunlight would also be ideal for using solar panels to generate electricity.

The three sites are also close to deep craters that have never seen the light of day, which make them possible caches of water ice. Water on the moon could be used as drinking water for a permanent lunar outpost and as a component of rocket fuel. The availability of water means that the moon could be a stepping-stone to Mars or even a near-Earth asteroid.

The International Space Station is another project many see as a stepping-stone. Next spring, the space station's first research mission will begin. A full-sized plastic model of a human head and torso, named Fred, first flew aboard the space shuttle, and it will fly again on the station. Full of mock organs and hundreds of sensors, Fred's purpose is to determine how dangerous long-term spaceflight can be to the human body. Low gravity has been known to disrupt perception, induce bone loss, and cause other problems (see "Surviving in Space," October 1999). And no one knows the effects of cosmic radiation because there's been little research on the type of multiyear missions that would be needed to reach Mars and other worlds.

Despite its ambitious scope, the $100-billion International Space Station is seen by many space enthusiasts as a drain on more daring human space exploration programs. Many scientists contend that the station is a white elephant siphoning money away from projects that are more worthy. Because it hovers inside Earth's protective magnetic field, say critics, it can't provide true readings on the effects of long-term radiation exposure. But for the time being, the space station is the only game in town.

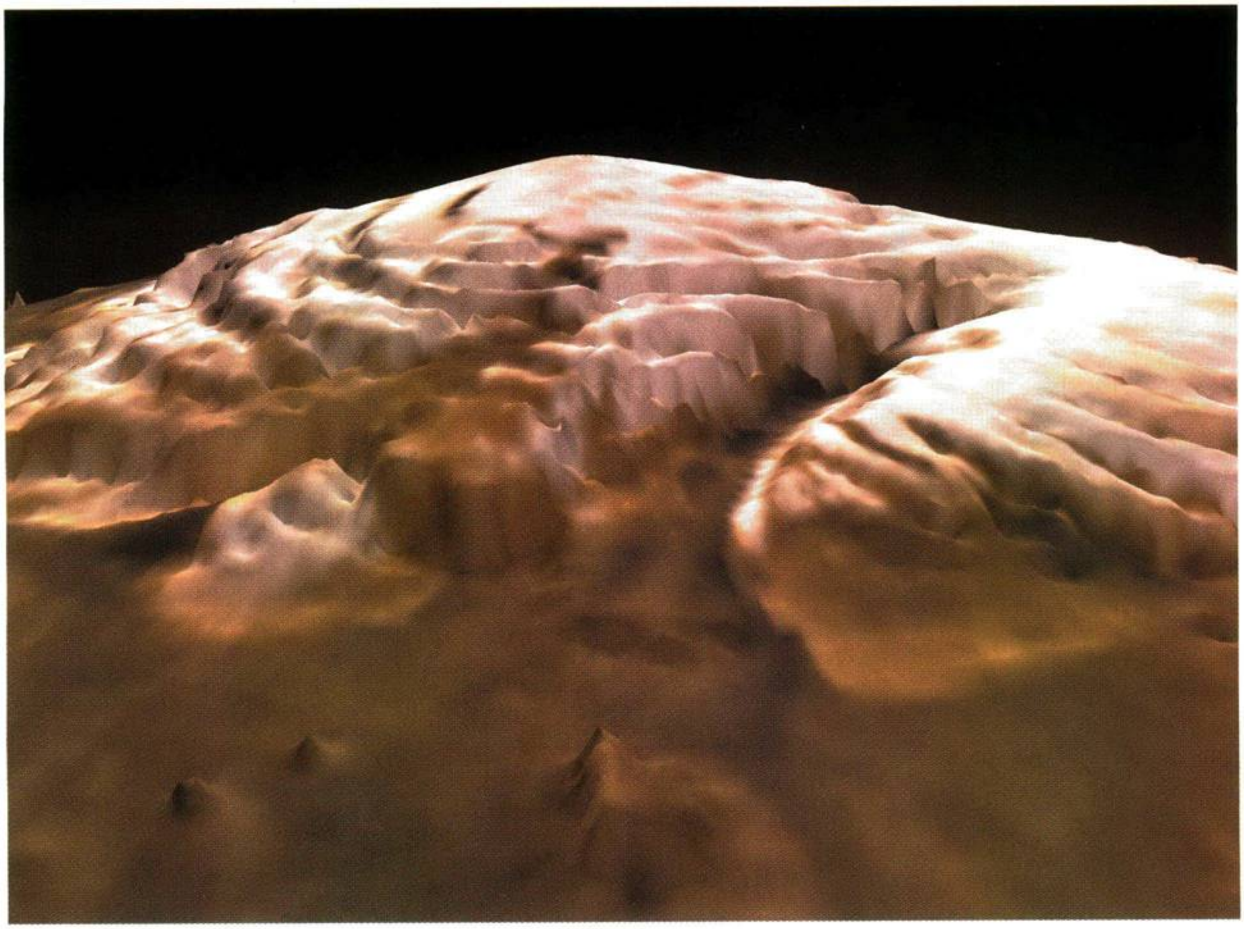
Onward to Mars

Mars looms on the more distant horizon. The most boisterous voice for sending humans to Mars is former Martin Marietta senior engineer Robert Zubrin, the exuberant leader of the Mars Society. Through conferences, articles, ardent lobbying, and a book titled *The Case for Mars*, Zubrin has become a one-man band for drumming up support for manned Mars missions.

Zubrin began his martian crusade as a reaction to President George Bush's 1989 Space Exploration Initiative, which called for a series of missions culminating in a manned trip to Mars. Initially conceived as a call-to-action similar to President Kennedy's famous speech that led to Apollo, SEI soon became quagmired by its $400-billion-dollar price tag. As it went down in flames, Zubrin developed an alternative.

The hallmark of Zubrin's Mars Direct plan is a sustainable Mars project — one that uses existing technology and a series of small rockets that would send landers to the martian surface before the first astronauts arrive. These landers could use martian raw materials to produce the oxygen and rocket fuel needed to sustain the astronauts on the surface and get them back home cheaply. Zubrin says this "live off the land" approach could shave tens of billions of dollars off an actual manned Mars mission.

Some engineers say Zubrin underestimates the cost and difficulty of a manned Mars mission. But it seems NASA has been listening. The most recent Mars mission concepts developed at Johnson Space Center use many of Zubrin's ideas, and official cost estimates now fall into a relatively affordable $50-billion price range. And while the time frame is still a matter of decades and not years, NASA will launch a series of robotic missions that are geared toward helping humans survive the grueling six-month trip to Mars, the probable 500-day surface stay, and the equally gruelling six-month return trip.



The north or south poles of Mars would be ideal locations for the first martian base, where possible ice-rich soil could be used for making rocket fuel or drinking water. NASA, Goddard Space Flight Center

For example, the 2001 Mars orbiter will look for useful minerals on the surface. The 2001 Mars lander will analyze the toxicity of the soils, measure the radiation in the environment, and see if Mars's carbon-dioxide-rich atmosphere can be "mined" to make oxygen (a key component of rocket fuel).

Then, in 2003, a series of missions will begin with a primary goal of acquiring martian samples and bringing them back to Earth. "We're preparing for what we believe to be an interval where the robots begin to create a beachhead for humans. We call 'em outposts," says Dan McCleese of the Jet Propulsion Laboratory, chair of the Mars Expeditions Strategy Group (see "Pursuing the Planets," page 52).

But when do we actually land on Mars? NASA declines to provide details of actual timelines for human missions. But behind the scenes there has been talk of a July 2019 mission to mark the 50th anniversary of the historic Apollo 11 moon landing.

To the Stars

Some scientists and visionaries find that places even as far as Mars are too confining. But what can take us into deep space? Whatever propulsion system is used, it will have to be far more advanced than the chemical rockets we've been using since World War II. Enter Marc Millis, leader of the breakthrough propulsion physics program at NASA's Lewis Research Center in Cleveland, Ohio. "Right now it's impossible to send humans on interstellar journeys," he says. "So we need undiscovered physics to get us around that."

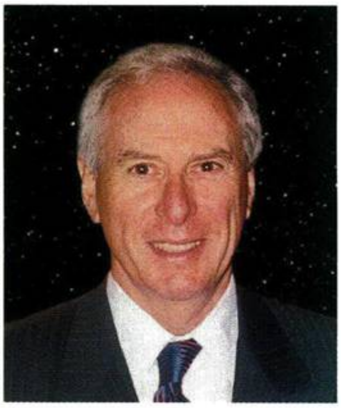
Millis has an inventory of propulsion systems that reads like a Trekkie's wish list. Wormholes. Warp drives. Anomalous weight losses. Spinning superconductors. Quantum tunneling. Bending spacetime. Dark matter. Antimatter. Space sails driven by lasers. But while the ideas sound far-out, Millis says that's what it will take to get us outside of the solar system in any reasonable amount of time. Humans probably won't be ready to undertake a pilgrimage to the stars for centuries or millennia to come.

But why leave this comfy planet in the first place? Zubrin and others espouse the idea that exploration is in our blood. Others believe that answering the question "Are we alone?" should be enough to motivate us to search for life on other planets.

Ultimately, going into space might be the only way to ensure our long-term survival. As Carl Sagan pointed out in his book *Pale Blue Dot*, humans will have to leave Earth someday to establish a planetary protection system against asteroids and comets. And if our descendants survive into the vast depths of time, the evolving sun will eventually force them to leave the beautiful blue world we call home. ▣

Aries Keck is a writer and producer of the radio program Science Update *in Washington, D.C.*

DAN GOLDI


AAS/Photograph by Richard Dreiser

On June 3, 1999, NASA administrator Daniel S. Goldin delivered a speech to the American Astronomical Society, which was holding its 100th anniversary meeting in Chicago, Illinois. After challenging astronomers to develop space telescopes that will image oceans and continents on life-bearing planets in distant planetary systems, Goldin outlined his vision of the far future, a vision of giant telescope arrays in space and intelligent microprobes that will travel to the stars. . . .

"You are probably wondering how to fund these dreams. NASA cannot rely on an expanding budget to pay for brute-force technological solutions to these scientific challenges. NASA is a tiny fraction of the federal budget but a large portion of the discretionary funds that Congress will look to once again to balance the budget. To respect budgetary constraints and to fund our dreams, NASA has developed some very simple principles.

Principle One: NASA will sustain a continuing line of cutting-edge technology for developing imaging and spectrographic systems in space. These may be large-aperture telescopes and interferometers, precision inflatable mirrors that could be positioned within our solar system, or giant apertures precisely positioned about 550 astronomical units (AU) from the sun, where the sun acts as a gravitational lens. We do not have to choose until those first wonderful spectra come back from neighboring planets. But we must be ready to make the best choices for our missions and must not be limited to merely doubling yesterday's telescope technology. We must constantly move forward.

Principle Two: We will only undertake smart designs and operations, leaving people to do what they do best: imagine and create. NASA will lead in developing neural nets and genetic algorithms that will allow our robotic voyagers to rely less on commands from Earth and more on their own learned experience, eliminating the need for rescue instructions from Earth, which may be light-days — or farther — away.

Just imagine our first interstellar probe that may give us new clues to new life-forms on planets in other solar systems. The Coke can-sized spacecraft will land on a passing asteroid two years after it is launched from Earth. Aboard the asteroid, the spacecraft will use its DNA-based biomimetic (life-imitating) system as a blueprint to evolve, adapt, and grow into a more complex exploring and thinking system.

It will ride the asteroid like a parasite until it transforms itself into its next evolvable state — an intelligent interstellar probe. It will use the asteroid's iron, carbon, and other materials to build its structure, nervous system, and communications. This reconfigurable hybrid system can adapt form and function to deal with changes and unanticipated problems. Eventually it will leave its host carrier and travel at a good fraction of the speed of light out to the stars and other solar systems. Such a spacecraft sounds like an ambitious dream, but it could be possible if we effectively utilize hybridized technologies.

Principle Three: We must constantly experiment in space. We will build a little, test a little, fly a little, fail a little, but learn a lot. We have an invigorated program to carry new technologies into space and validate them — the New Millennium Program (see "Unveiling Tomorrow's Technology," page 56) — which is open to all advanced ideas. It centers on technology validation with fast turn-around times of only a couple years and costs of just a few million dollars, not hundreds of millions.

Principle Four: Scientists must have maximum flexibility in placing satellites to assure optimal science return. Future observatories may perform best at the second Lagrangian point, where the sun and Earth are

N’S VISION

constantly on one side, making thermal design, power generation, and communications far more effective and simple. Or they may need to fly beyond the asteroid belt, where the sky is a few hundred times darker than it is at 1 AU. Future scientific discoveries may require imaging from the sun's gravitational lensing point at 550 AU. From this location, we may map the surface features and monitor characteristics of target planetary systems with giant telescopes that look for planetary emissions from the visual and the infrared and out to the radio wavelengths.

Wherever your science program takes us, NASA must be prepared to supply the ride. For years NASA launched massive spacecraft, but recently, we have reduced spacecraft size and cost by almost a factor of 10. But things such as telescope aperture size cannot be shrunk, and as long as it costs $10,000 to put one pound of payload in Earth orbit, we will be forced to make our biggest space-based telescopes lightweights.

However, with operating costs 10 to 100 times lower than today, with the reliability of a commercial airliner and the payload capacity of the Shuttle, an advanced reusable launch vehicle could eliminate this burden. With advanced launch technology, weight will not be the absolute constraint that it is now.

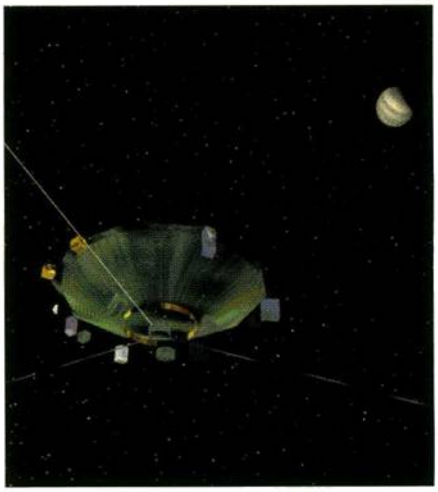
To leave Earth orbit now, we rely on heavy chemical rockets, and we are launching mostly fuel. The Deep Space 1 probe NASA launched last fall is the first to use electric propulsion. It carries only 80 kilograms (176 pounds) of fuel. In the future, solar electric propulsion will be the system of choice for rapidly moving about the inner solar system — out to about Jupiter. With advanced systems we can move larger payloads to Jupiter's orbit to avoid the glare of dust.

If the payload is very small, light sails pushed by the pressure of sunlight or laser energy may be an option. At Earth, the available thrust is about a milligram per square meter at best, but the pressure is unrelenting. Sails could be accelerated for months and then they could coast to their destination.

Reaching beyond the planets may require propulsion systems with much higher energy-density processes than the combustion we currently use. Such systems might allow us to get out to the sun's gravitational lensing point and stop in 10 years or less. All that is necessary is to dream and think creatively once again in America.

OUR FIFTH PRINCIPLE: I am challenging the country's technologists to produce advances in optical systems that are an analog of Moore's Law, where computing power doubles every 18 months. At the same time, price is reduced as much as 50 percent.

In honor of one of the early visionaries, this doubling of telescope collecting power could be called 'Hale's Law.' George Ellery Hale got the century off to a terrific start by building ever-larger telescopes, but for the past several decades, telescope collecting area has doubled only every 25 years! What should the time frame be? Ten years? Five years? Three? You tell me.



Future spacecraft will be miniature. NASA/JPL

In a decade or so, the technology behind the Next Generation Space Telescope's 8-meter mirror will be obsolete, so the country's most creative technologists should already be at work today on optical systems 3 to 10 times larger in diameter, and 10 — or even 100 — times less dense than NGST. And we will want baselines for the interferometers of not just tens of meters, but thousands of kilometers!

To aid this growth, we at NASA have made the development and testing of innovative optical systems and precision free-flying spacecraft one of NASA's highest technological priorities. We will make it a priority of NASA to fund those technologists who will not be limited by their dreams.

My friend, Roger Angel (a telescope designer at the University of Arizona), has been a torchbearer with the wonderful lightweight mirrors that he

"WE MIGHT EVEN BE ABLE TO SEE SIGNS OF BACTERIA, VAST FOREST FIRES ON OTHER PLANETS, OR THE EMISSIONS FROM CITIES."

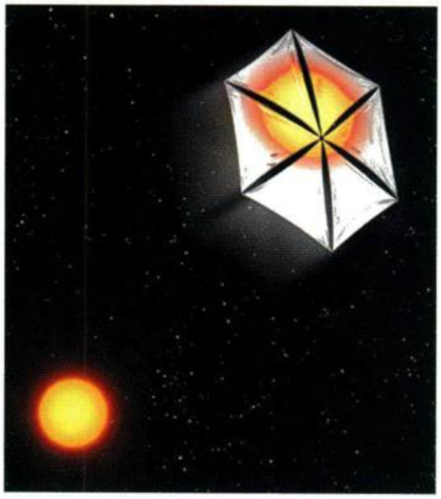
has designed and his work with arrays of flat collectors — designs for future precision optical systems, with surface densities more than two orders of magnitude lighter than we built for the Hubble Space Telescope (HST). But, Roger, please, no more creative ideas on what to do with HST: After two decades of forefront scientific research, it will be time for that spacecraft to go into well-deserved retirement.

WHICH BRINGS ME TO THE SIXTH AND FINAL PRINCIPLE: Let it go. Given the budget constraints science and technology projects face, we need to be willing to let go of old observatories when new technologies are ready for launch. We tend to hold tight to older technologies because we are comfortable with them. But those older systems consume a great deal of money for maintenance and updating, preventing us from developing and launching new and improved systems. We cannot continue on this path.

These principles should help us launch into a brave new future in space, but as I have said before, it will require dreaming big dreams and looking far into the future.

Perhaps a decade after we have discovered several dozen warm and wet worlds in our stellar neighborhood, even lighter-weight optical structures will be ready, and we may choose as our next step apertures of 100 meters and a baseline of 1,000 kilometers. Even while we are building such a system, our technologists will already be at work on 1-kilometer apertures and baselines of 10,000 kilometers and propulsion systems for rapid travel to 550 AU.

With these giant observatories, future observational astrobiologists might produce the first crude images of newly discovered planets. Scientists will debate the structure of continents and oceans, weather patterns, climates, storms, and the nature of seasons on dozens of new worlds, just as many of you today are debating the nature of the planets newly discovered around the star Upsilon Andromedae.



Interstellar spacecraft could be accelerated by giant solar sails. Paulett Liewer (NASA/JPL)

The new century's students will be able to study the accretion of planetesimals and the impacts between young planets in newly-forming star systems. Larger systems could reveal lakes and rivers, the growth and destruction of forests, and the melting of ice caps could be revealed in planets around the nearest thousand stars. We might even be able to see global mats of algae or signs of bacteria reminiscent of the early Earth, vast forest fires on other planets, or the emissions from cities.

Let us not forget that while we are searching for life, we are also producing incredible tools for all astronomy. As we perfect the control of these giant apertures, astronomers might use them to first gather radio and submillimeter light, perhaps from young stars halfway across the universe.

The scientists of the mid-century will use the same powerful optical systems to investigate the outer portions of the accretion disks surrounding supermassive black holes in the Virgo Cluster of galaxies. Imagine the spectacle of being able to watch the torrential effects of matter spiraling downward into this gravitational abyss. Their colleagues will be equally vigorous in investigating the processes of formation of the very first stars — and the generation of the first elements necessary for life — studied in detail from across the universe.

Well, this has been quite a trip into the future, hasn't it? But I know that the torchbearers of the American Astronomical Society are equal to grand challenges. That's why I presented these possibilities to you today.

T.S. Eliot could have been speaking about the journey we embark on today when he said: "Only those who will risk going too far can possibly find out how far one can go."

Thank you for rising to yet another challenge. And thank you for daring not to be limited by your dreams!" ■

Daniel S. Goldin has been NASA Administrator since 1992. A full transcript can be read at www.nasa.gov/bios/goldin_speeches.html

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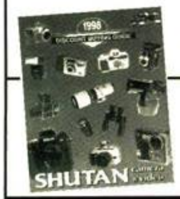

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by Martin Ratcliffe and Alister Ling

▶ If Jack Frost is nipping at your nose and you and your observing buddies are dressed up like Eskimos, it must be December. Making the season bright are the duo of Jupiter and Saturn, standing resplendent at dusk every evening high in the southeast. Ruddy-colored Mars continues to glow ever more dimly as it slinks away in the west and spends most of December in Capricornus the Sea Goat, joining its distant relatives Uranus and Neptune. Regardless of whether or not you've been good this year, you're guaranteed some great gifts, such as the appearance of the Geminid meteor shower and stars doing the tango with the moon.

Mars sets by 9 P.M. local time and each night moves slightly farther east against the backdrop of Capricornus. After passing south of **Neptune** on November 28, Mars's track takes it within a degree of **Uranus** on December 13. A low-power eyepiece should show Mars, Uranus, and Theta (θ) Capricorni in the same field of view, shining at magnitudes 1.0, 5.9, and 4.1, respectively. The obvious contrasting color between bluish-green Uranus and orange Mars will be quite alluring. The mind-bender will be the realization that Mars lies a mere 1.7 astronomical units from Earth, but Uranus resides at a sprawling distance of 18.75 astronomical units, or 1.75 billion miles (1 AU = 93 million miles). A simple comparison of their relative sizes — Mars appears almost double the apparent diameter of Uranus, yet Uranus is more than ten times farther away — shows Uranus to be a true giant planet compared to diminutive Mars. The waxing crescent moon lies 2° east of Mars on December 12, which coincides with the rise in activity of the Geminid meteor shower.

The peak of the Geminids occurs on the morning of December 14, so the best activity will be seen on the night of December 13/14. The moon sets before midnight, by which time the radiant in Gemini lies high in the darkened southeast-

Orion is the most recognizable signpost in the winter sky. The Horsehead and Orion nebulae — and this month, Hebe — can all be found within the constellation.

Alan Dyer

DECEMBER 1999

2 Pluto is in conjunction with the sun, 7 P.M. EST
Mercury is at greatest western elongation (20°), 8 P.M. EST (page 74)

3 The moon passes 3° north of Venus, 4 P.M. EST

5 The moon passes 3° north of Mercury, 8 P.M. EST

7 New moon is at 5:32 P.M. EST

8 The moon is at apogee (252,665 miles from Earth), 6:04 A.M. EST

9 Asteroid Hebe is at opposition, 1 A.M. EST

10 Asteroid Amphitrite is at opposition, 11 P.M. EST

11 The moon passes 0.07° south of Neptune, 5 P.M. EST

12 The moon passes 0.6° north of Mars, 2 P.M. EST
The moon passes 0.2° south of Uranus, 4 P.M. EST

13 Mars passes 0.7° south of Uranus, midnight EST

14 Geminid meteor shower peaks (page 74)

15 First quarter moon is at 7:50 P.M. EST

17 Mercury passes 5° north of Antares, 3 A.M. EST

18 The moon passes 4° south of Jupiter, 1 A.M. EST

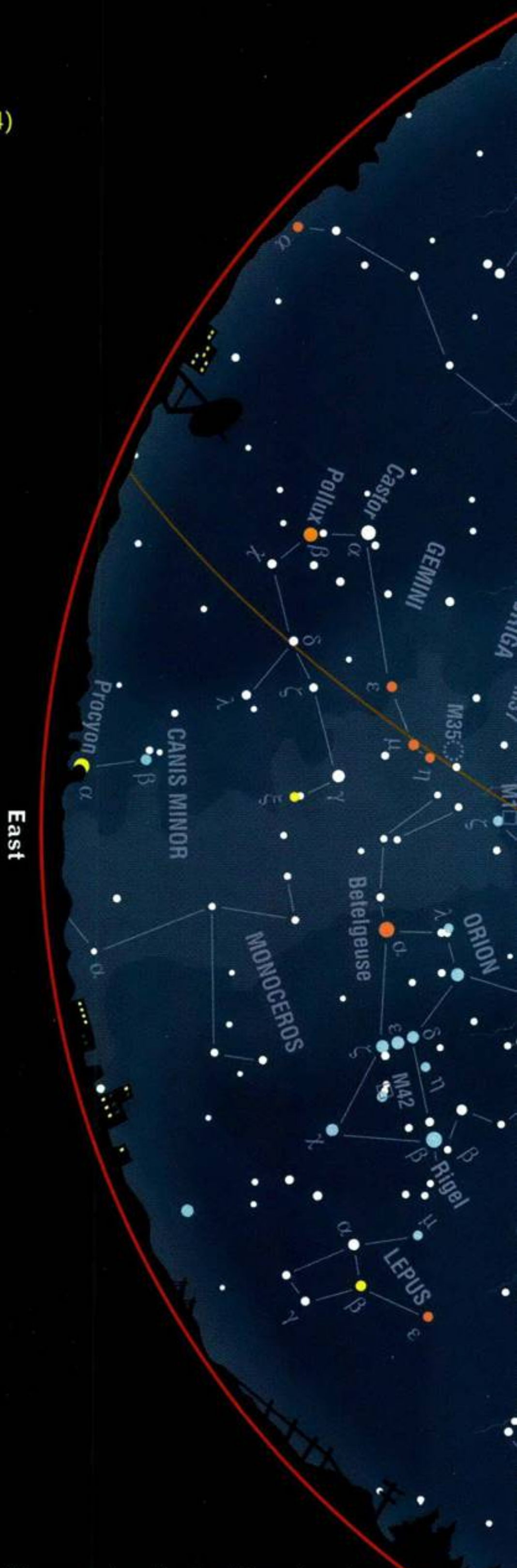
19 The moon passes 3° south of Saturn, 4 A.M. EST

21 The moon passes 1.3° north of Aldebaran, 4 A.M. EST

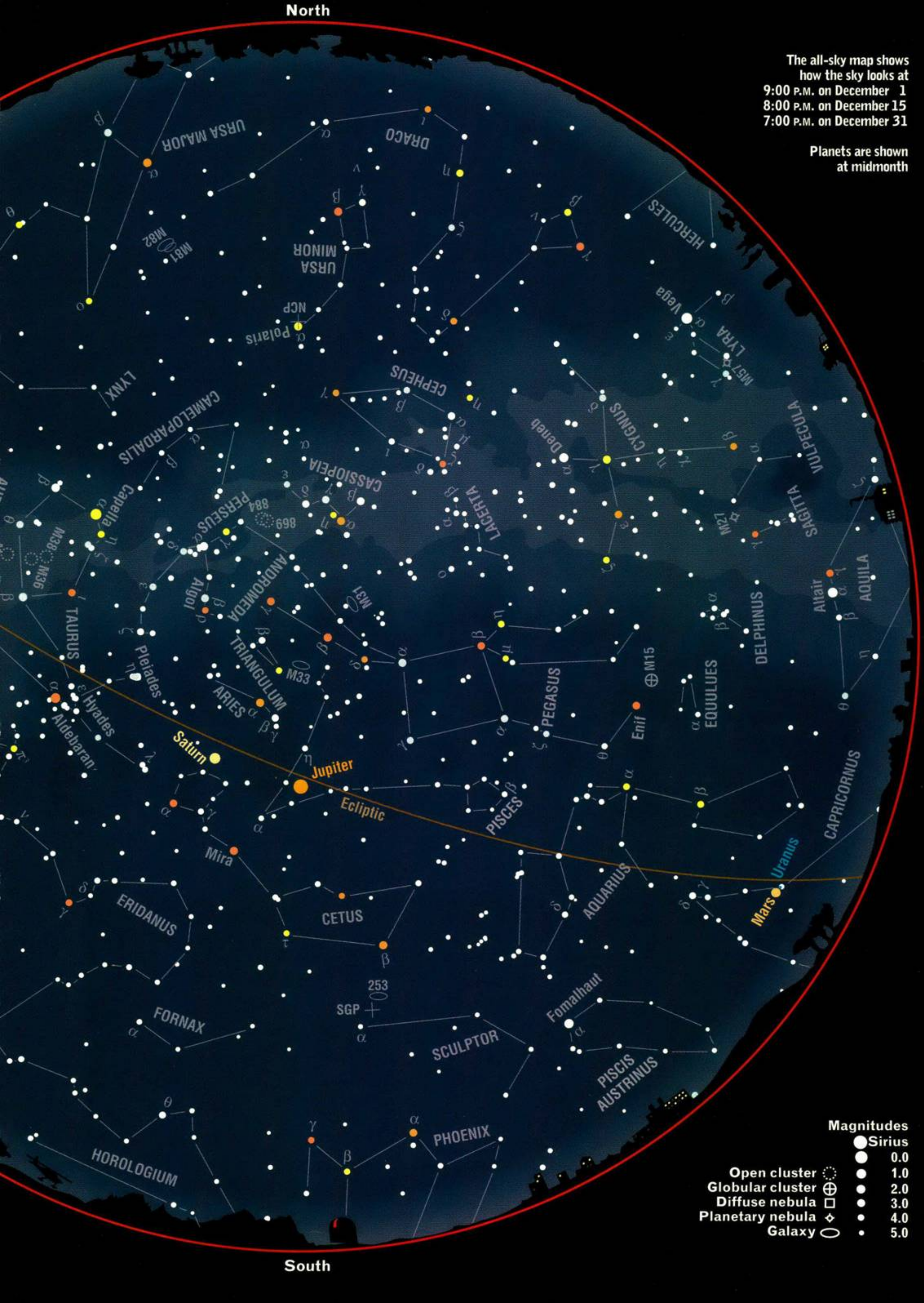
22 Winter solstice is at 2:44 A.M. EST
The moon is at perigee (221,614 miles from Earth), 5:55 A.M. EST
Full moon is at 12:31 P.M. EST

29 Last quarter moon is at 9:04 A.M. EST

Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
			1 🌘	2 🌘	3 🌘	4 🌘
5 🌘	6 🌘	7 🌑	8 🌑	9 🌒	10 🌒	11 🌒
12 🌒	13 🌒	14 🌓	15 🌓	16 🌓	17 🌔	18 🌔
19 🌕	20 🌕	21 🌕	22 🌕	23 🌕	24 🌕	25 🌕
26 🌖	27 🌖	28 🌖	29 🌗	30 🌗	31 🌘	



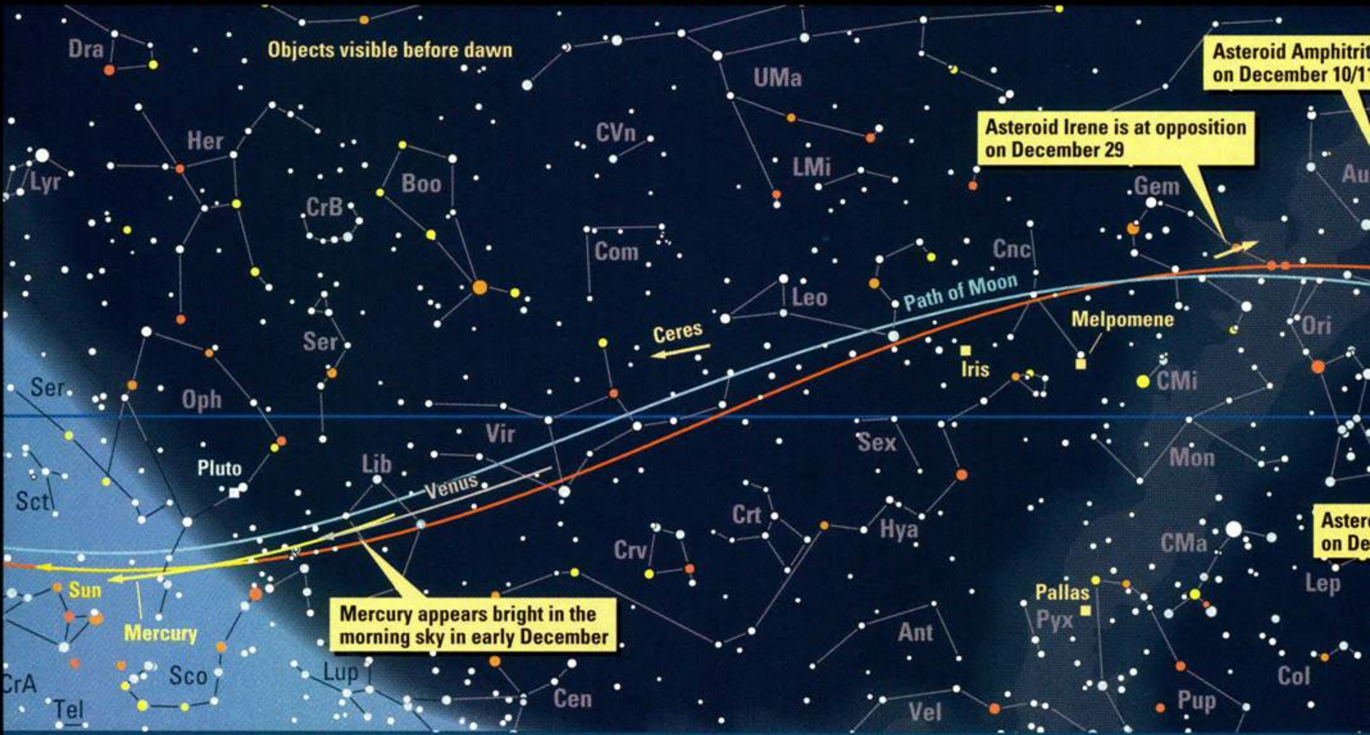
This map portrays the sky at times shown in the upper right corner of the page. Located just outside the map are the four directions: north, south, east, and west. To find stars above your horizon, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.


North
URSA MAJOR
DRACO
HERCULES
URSA MINOR
M81
M82
NCP
Polaris
Vega
LYRA
M57
LYNX
CAMELOPARDALIS
CEPHEUS
CYGNUS
Deneb
VULPECULA
CASSIOPEIA
LACERTA
SAGITTA
M27
Capella
PERSEUS
884
869
M38
M36
ANDROMEDA
Algol
M31
DELPHINUS
Altair
AQUILA
TAURUS
Pleiades
TRIANGULUM
M33
ARIES
PEGASUS
M15
EQUULUES
Enif
Hyades
Aldebaran
Saturn
Jupiter
Ecliptic
PISCES
West
Uranus
Mars
CAPRICORNUS
Mira
ERIDANUS
CETUS
AQUARIUS
253
SGP
FORNAX
SCULPTOR
Fomalhaut
PISCIS AUSTRINUS
PHOENIX
HOROLOGIUM
South
Magnitudes
Sirius
0.0
1.0
2.0
3.0
4.0
5.0
Open cluster
Globular cluster ⊕
Diffuse nebula □
Planetary nebula ◇
Galaxy

The all-sky map shows
how the sky looks at
9:00 P.M. on December 1
8:00 P.M. on December 15
7:00 P.M. on December 31

Planets are shown
at midmonth

THE PATH OF THE PLANETS

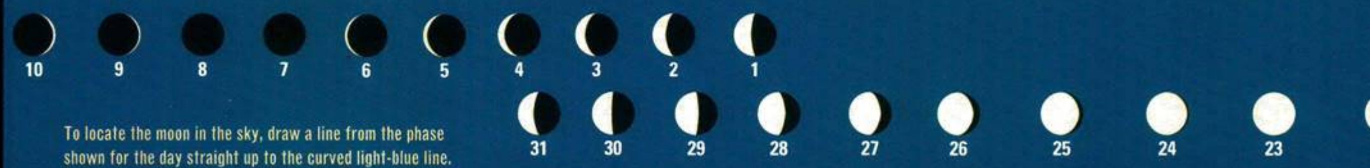

Dra
Objects visible before dawn
UMa
Her
CVn
LMi
Lyr
CrB
Boo
Gem
Au
Com
Cnc
Leo
Path of Moon
Ser
Ceres
Melpomene
Ori
Iris
Ser
Oph
CMi
Vir
Sex
Mon
Pluto
Lib
Venus
Sct
Crt
Hya
CMa
Crv
Lep
Sun
Pallas
Pyx
Mercury
Ant
CrA
Sco
Lup
Col
Tel
Cen
Vel
Pup

Asteroid Amphitrit
on December 10/1

Asteroid Irene is at opposition
on December 29

Mercury appears bright in the
morning sky in early December

Astero
on De


10
9
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6
5
4
3
2
1
31
30
29
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25
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23

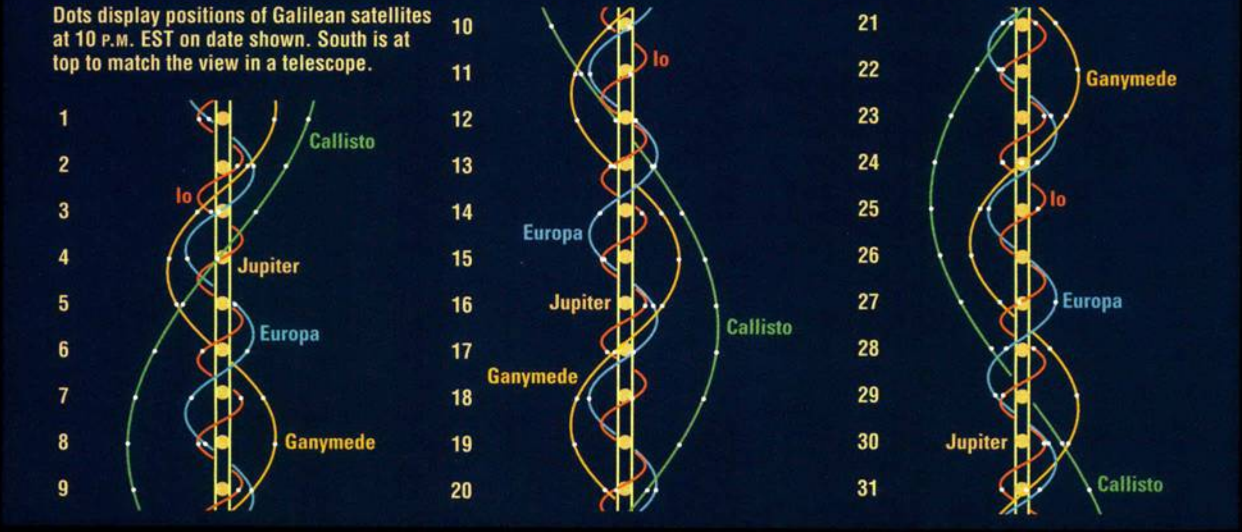
To locate the moon in the sky, draw a line from the phase shown for the day straight up to the curved light-blue line.

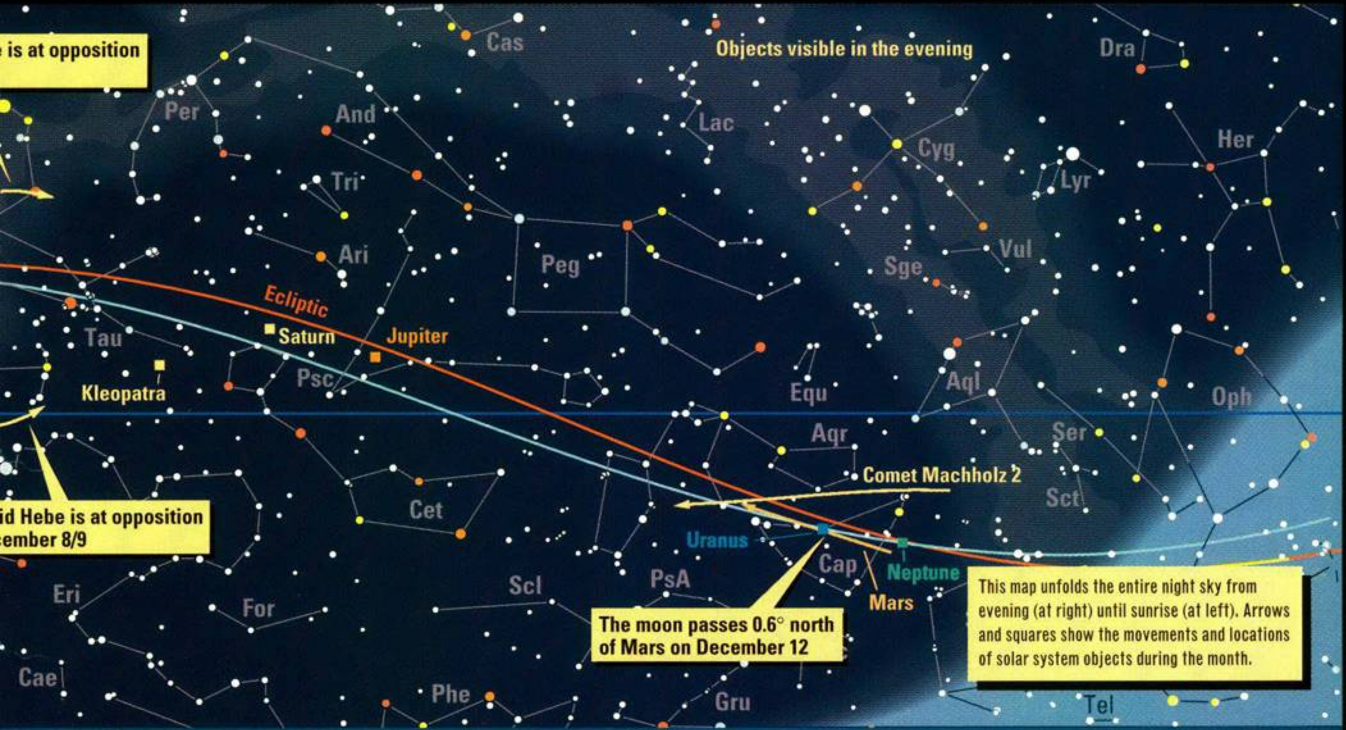
10"
S
W
E
N

PLANETS	MERCURY	MERCURY	VENUS	MARS	JUPITER
Date	December 1	December 15	December 15	December 15	December 15
Magnitude	−0.4	−0.5	−4.2	1.0	−2.7
Angular Size	7.0"	5.4"	16.4"	5.3"	45.2"
Illumination	55%	86%	70%	91%	99%
Distance (AU) from Earth	0.958	1.245	1.020	1.755	4.364
Distance (AU) from Sun	0.342	0.419	0.719	1.384	4.963
Right Ascension (2000.0)	15h06.2m	16h15.2m	14h35.8m	21h09.1m	1h34.9m
Declination (2000.0)	−14°53'	−20°11'	−12°48'	−17°44'	8°27'

JUPITER'S MOONS

Dots display positions of Galilean satellites at 10 P.M. EST on date shown. South is at top to match the view in a telescope.



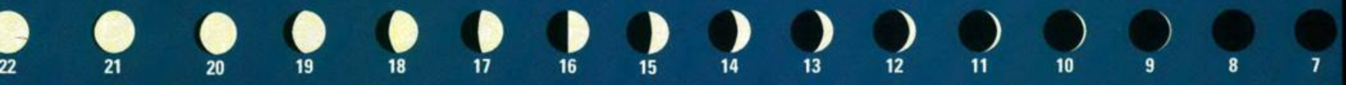

Cas
Objects visible in the evening
Dra
Per
And
Lac
Cyg
Lyr
Her
Tri
Ari
Peg
Sge
Vul
Ecliptic
Tau
Saturn
Jupiter
Psc
Kleopatra
Equ
Aql
Oph
Aqr
Ser
Comet Machholz 2
Sct
Cet
Uranus
Cap
Neptune
Mars
Eri
For
Scl
PsA
Cae
Phe
Gru
Tel

e is at opposition

id Hebe is at opposition
ember 8/9

The moon passes 0.6° north of Mars on December 12

This map unfolds the entire night sky from evening (at right) until sunrise (at left). Arrows and squares show the movements and locations of solar system objects during the month.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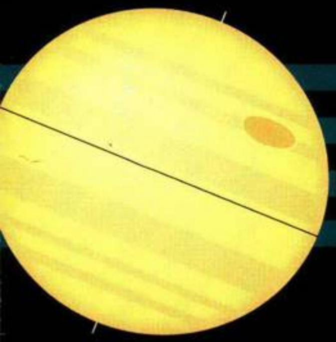
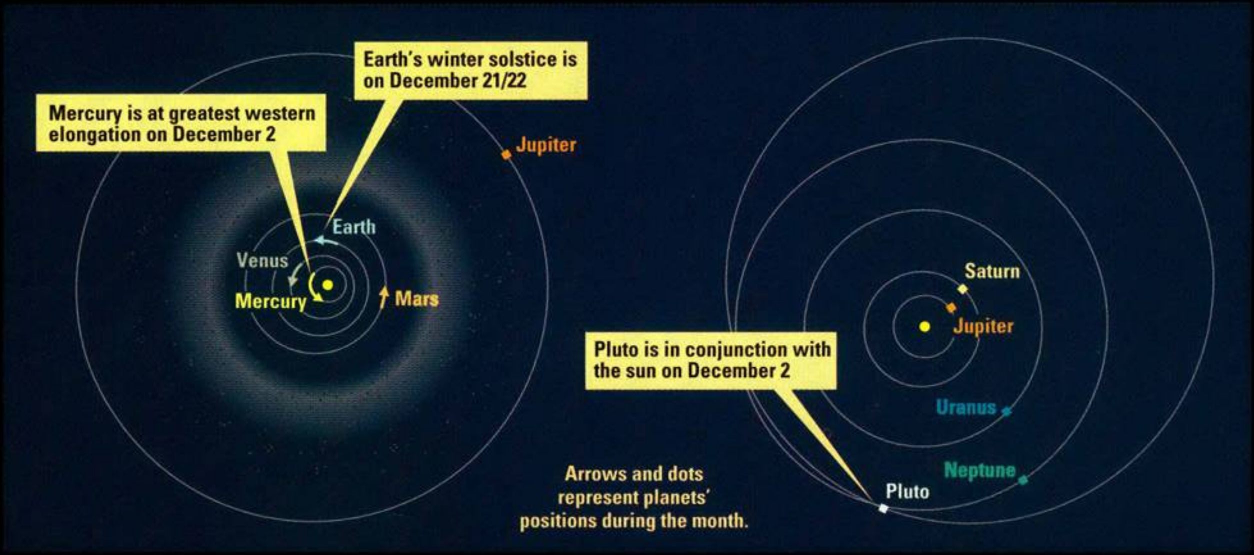


SATURN	URANUS	NEPTUNE	PLUTO
December 15	December 15	December 15	December 15
0.0	5.9	8.0	13.9
19.7"	3.4"	2.2"	0.1"
100%	100%	100%	100%
8.428	20.521	30.868	31.164
9.188	19.922	30.121	30.219
2h37.6m	21h06.7m	20h19.4m	16h43.1m
12°44'	–17°16'	–19°21'	–11°19'

THE PLANETS IN THEIR ORBITS


Jupiter
Earth
Venus
Mercury
Mars
Saturn
Jupiter
Uranus
Neptune
Pluto

Earth's winter solstice is on December 21/22

Mercury is at greatest western elongation on December 2

Pluto is in conjunction with the sun on December 2

Arrows and dots represent planets' positions during the month.

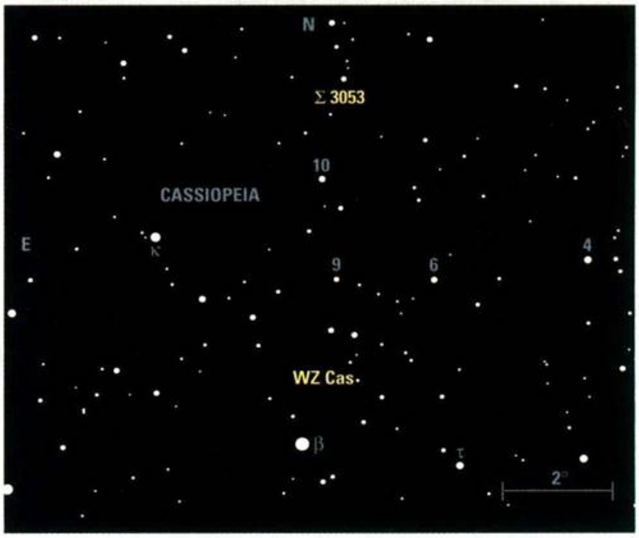
First Views: Colorful Doubles in Cassiopeia

Sometimes the most delightful sights in the sky are unexpected and make nights out memorable. On some night you may be star-hopping your way to a faint star cluster and be startled to see a striking pair of colored stars, like those in Cassiopeia the Queen.

To get to the far northern reaches of Cassiopeia, face north and look high above Polaris to find upside-down Cassiopeia, in the shape of an "M." If you start on Beta (β) Cassiopeia, the leftmost star of the "M," and head back to Polaris by about 7°, a bit more than a typical binocular field of view, you'll land at the bottom end of a stick with a triangle attached. This bottom star is Struve 3053 (Σ3053).

This pair, discovered by Otto Struve, almost rivals the famous Albireo and is suitable for small telescopes even from a city. The stars glow at magnitudes 5.9 and 7.3 and are separated by a comfortable 15", about half that of Albireo. The brighter one is a pleasant gold, offsetting the cool blue of the fainter component.

How about a double with as much color as Albireo? You'll never find WZ Cassiopeiae in a double star list because its line of sight companion is not close enough to make it a physical double, at twice the separation of Albireo. Because the duo is a fair bit fainter, small scopes don't do it justice. But in an 8-inch or larger instrument, it is remarkable. WZ Cas is an orange semi-regular variable, hovering around 10th magnitude. The blue companion is a shade paler than Albireo's, but the contrast to the deep-orange hue of the variable is without compare.



All illustrations: *Astronomy*/Elisabeth Rowan

WZ Cas lies only 1° from Beta Cas, just to the lower left during evening hours, at 0h01.3m, +60°21' (2000). You can locate Σ3053 at 0h02.6m, +66°06' (2000). Take care when using charts because north is down in this part of the sky.

ern sky. Normally, 60 meteors an hour are visible at the peak of activity. Shooting stars may not be mistletoe, but with some luck they may have the same effect.

Throughout this month the most dominant features of the night sky are also the most dominant members of our solar system's family — **Jupiter** and **Saturn** — who sparkle like a pair or ornaments. They lie only 16° apart. The biggest and brightest, Jupiter, lies to the west of Saturn and shines at a dazzling magnitude –2.7 — making it the most luminous object in the night sky not counting the moon. Jupiter lies in Pisces the Fish. Nearby, Saturn shines at magnitude 0.2 in Aries the Ram.

Almost any telescope will reveal a great amount of detail in Jupiter's turbulent atmosphere, although all observers are at the mercy of our own planet's atmosphere and its capricious seeing. Smaller scopes will see the major features, such as the dark equatorial belts and the Great Red Spot. Also easy catches are the occasional eclipses or shadow transits involving the four principal moons: Io, Europa, Ganymede, and Callisto. Because each of the moons orbits Jupiter in its equatorial plane and also along our line of site, every time a moon passes in front of or behind Jupiter, we see a transit or occultation. Quite often only two or three Galilean moons are visible because of the frequent eclipses resulting from the satellites' fast orbital periods.

Accurate timing of these events was once used to calculate the speed of light. Careful predictions of occultations were made based upon knowledge of the orbits of the moons. However, the Earth-Jupiter distance changed throughout the year by a distance equivalent to Earth's orbital diameter. When Earth was farther away from Jupiter, the events would occur later than predicted due to the extra light-travel time across Earth's orbit. The resulting difference between the predicted and observed timings was just one of the ingenious insights discovered by our ancestors.

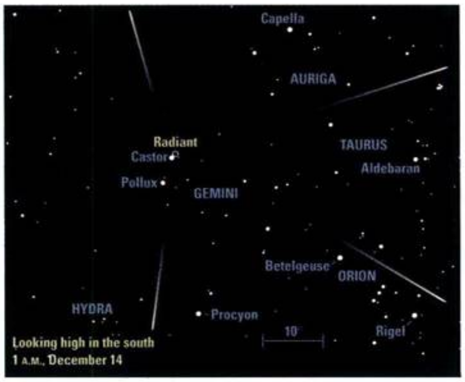
Jupiter's cloud system scuttles around the giant planet very quickly — in less than ten hours. Fine detail appears to move noticeably across the face of Jupiter within 30 minutes. Timing the moment when a feature crosses the central meridian of the planet (an imaginary line between the two poles of the planet) will allow the longitude of the feature to be calculated. Tables of the longitude of the central meridian at the beginning of each day are given in publications such as *The Observer's Handbook* published by the Royal Astronomical Society of Canada and the *Handbook of the British Astronomical Association*. Repeated timings of these features can determine if they are drifting in longitude — and many do, such as the Great Red Spot, the most obvious cloud formation on the face of Jupiter. See if there are any other, more subtle cloud formations that you can track.

Observers of Saturn are not so lucky as far as having atmospheric details to look at — yet the sheer beauty of its ring system that wraps delicately around the yellowish disk makes up for the lack of detail. Saturn currently lies 33 million miles closer than its average distance of 888 million miles. By the year 2003 Saturn reaches perihelion at 839 million miles.

Saturn wanders slowly against the faint southern stars of Aries the Ram this month. A nearly full moon passes 3° south of the planet on December 19. The disk of the planet has an apparent diameter of 18", but the rings, tilted 19° to our line of sight, divulge their southern face, spanning almost 45" by 15".

Shining 16° south of Saturn, the enigmatic variable star Mira (Omicron [o] Ceti) lies in the belly of Cetus the Whale. Mira was the first long-period variable star to be discovered. On the night of August 13, 1596, a Dutch amateur astronomer by the name of David Fabricius noted a fairly bright star in Cetus where none had been seen earlier. Imitating Fabricius's powers of observation, you can emulate his discovery because in the weeks and months that follow Mira will fade as it did in 1596. By making two observations a month and comparing the brightness of Mira to nearby stars, its waning glory can be tracked. Alpha (α) Ceti glows at magnitude 2.7, Gamma (γ) Ceti at magnitude 3.6, and Delta (δ) Ceti at magnitude 4.1. After a few months you will need binoculars to follow Mira's light curve. Be wary

A Gem of a Meteor Shower



Looking high in the south
1 A.M., December 14

Two main events signal the impending holiday season: the arrivals of the first fruitcake and the Geminid meteor shower. Luckily for us, at least one of them constitutes a feast . . . for the eyes.

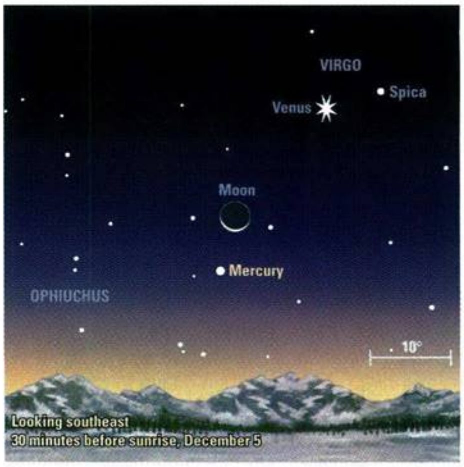
The larger number of bright meteors differentiates the Geminids from August's Perseids. If you must observe from the city, you'll see more action simply because the skyglow really kills the fainter Perseid meteors.

The dust grains that vaporize high in Earth's atmosphere are generally larger during the Geminid meteor shower. Small pebbles screaming in at 20 miles (35 km) a second blaze into bolides, really bright meteors. The shower's orbit resembles that of asteroid 3200 Phaethon, which suggests that the shower contains rocky fragments instead of flakier comet dust. Such metallic debris can blaze with different colors, usually blue.

Start observing on Monday evening, December 13. If you are heading to a dark site in order to catch the peak of the shower near dawn on the 14th, wait until the moon sets, just before midnight. Finally, remember that you can never be overdressed for a winter's night.

Frank Zullo

Mercury's Morning Jaunt



Looking southeast
30 minutes before sunrise, December 5

Mercury's poor reputation is undeserved. If you know when and where to look, spying Mercury with the unaided eye is a snap. If you wait a couple weeks too long, however, you can miss it.

Start during the last week of November, near 6 A.M. (about 45 minutes before sunrise), and with binoculars scan about one field of view above the horizon, keeping to the lower left of brilliant Venus. Mercury is the very next object visible. It shines at magnitude 0.3.

The thin, waning crescent moon joins Mercury on December 5, a bit more than a binocular field to its upper right. If Mercury seems easier to see, that's because it is. The tiny, innermost planet has gained almost a full magnitude of brightness in the last 10 days. The moon, Mercury, and Venus (floating above the pair) should make for a pretty scene.

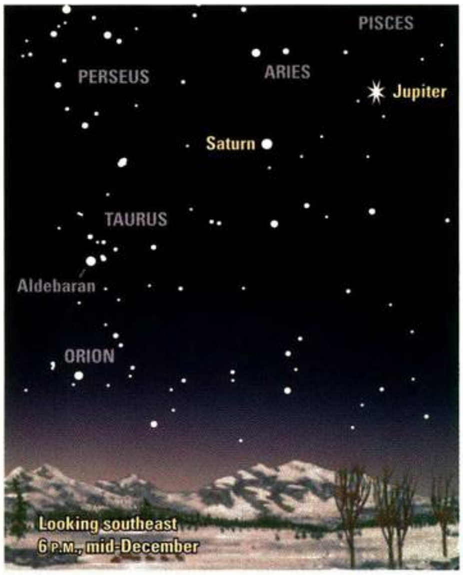
After the 15th, Mercury begins its swing behind the sun, dropping into the bright horizon glow and becoming more difficult to find without binoculars.

of any prediction of the magnitude of Mira before you go out to observe — Mira has a habit of surprising even the most-seasoned observers. Yet this fascinating variable will introduce you to the subtleties of the universe that few ever notice.

Another fascinating subtlety of the night sky occurs when the moon passes in front of a star in an event called an occultation. The moon's path cuts a swath a half-degree wide across the entire sky each month, so it's only natural to expect occultations every night. Most are of dim stars, but this month a couple bright stars are occulted for North American observers, and European observers are treated to an occultation of Mars. (See "The Disappearance of Mars," page 77.) The Mars event takes place in daylight in the United States, but western Europe sees the event in the early evening of December 12. As the crescent moon dips to the southwest, notice the 1st-magnitude orangey-red "star" lying close by. Before moonset, the moon will cover the Red Planet — an event worth watching through a telescope. See how long the moon takes to cover Mars's 6" diameter.

A brilliant full moon occults magnitude 4.1 Nu (ν) Geminorum on December 22. The event occurs shortly after moonrise for observers in the western half of the United States but is better placed above the horizon for observers farther east. In the central United States, the event occurs at approximately 7:53 P.M. CST, with those farther east seeing the event occur later and those to the west a few minutes earlier.

Jupiter and Saturn in Focus



Looking southeast
6 P.M., mid-December

Take advantage of the gas giants' prominence in the nighttime sky to get some fantastic views. In a few months, they sink toward the horizon and become more affected by Earth's turbulent atmosphere.

The never-ending swirls of cloud-top tapestry on Jupiter are a marvel to behold when the seeing is good. With an 8-inch scope it's possible to catch white ovals near the Great Red Spot. For Saturn, we are positioned to watch the shadow of the globe move out onto the rings. Last month at opposition the disk was in our line of sight. During this month, the slender black line right next to the eastern limb will fill out to an obvious dark swath.

To get the most out of planet observing, good seeing and a well-adjusted telescope are needed. Some nights the atmosphere swirls as if you have been transported into the swimming scenery of van Gogh's *Starry Night*. Other nights a perfect sky is lost because your scope hasn't been given the chance to cool down. As the evening air temperature drops, your lenses, mirrors, cells, tubes and other componenets give off heat, much of it as wafts of lower density air across the light path.

You can control these tube currents by placing the scope outside for 30 to 60 minutes before you observe to let it cool down while you relax inside. Bigger scopes have thicker mirrors, so they typically need a longer cooling period. Small fans can really speed up the wait.

The Lighter Side of Venus

Carl Faulkner

Venus begins a slow descent back toward the sun, displaying a gradually fattening phase and shrinking in total size along the way.

Venus now occupies the backside of the orbital racetrack relative to us, which is why it is thicker than a half-moon shape. Earth's moon lies a binocular field above Venus on December 3 and below left on the 4th. Since the moon is almost between us and the sun, it displays a crescent phase.

Try observing Venus during the day through a telescope. Daytime observing eliminates glare, and the blue-sky background makes for a nice change of pace. The trick, of course, is knowing where to look. Because Venus has a considerably different declination than the sun, using the simple time offset technique just won't work.

You'll need an equatorial mount that's roughly aligned with the pole. Center on the sun (with finder and main scope front caps on) and set your right ascension according to an ephemeris. Now offset to Venus' position and it should be in the finder. Slide in an eyepiece, uncap the scope, and you're off to the races.

Observer's Challenge: A String of Pearls

Lee C. Coombs

NGC 7788 (left) and NGC 7790 (right) are open clusters that dwell in the outer reaches of Cassiopeia.

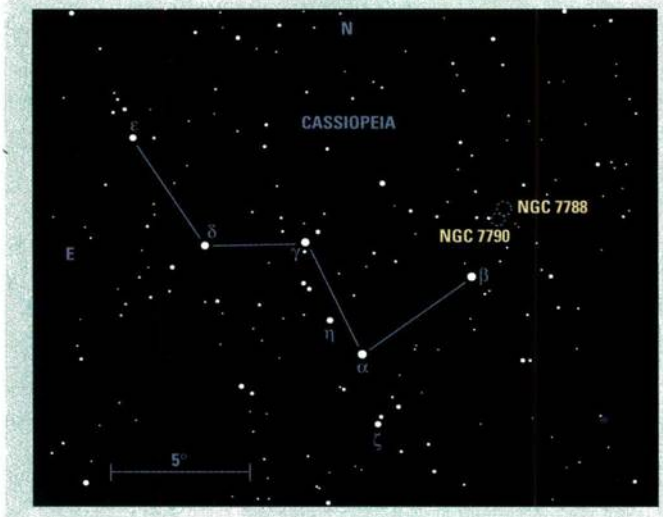
Star clusters are in many ways the most varied class of deep-sky object. Each has its own character, beyond brightness or number of stars. Star clusters can be brilliant enough to shine through city lights or so faint as to be mistaken for galaxies. They span the gamut from rich with faint stars to a mere smattering of bright ones.

A 3-inch scope is all you need to start trekking along this chain of open clusters. To see them well, you will need to escape to dark, country skies and avoid interference from the moon. Not far from the upper right of Cassiopeia's "M," 2° away, lies the pair NGC 7788 and NGC 7790, which are separated by less than the width of the moon.

NGC 7790 is readily visible in binoculars, with NGC 7788 being a bit tougher. In a 3-inch refractor, NGC 7790 appears to have two parts, a coarse group of 8 to 10 brighter stars, with an unresolved patch of light tucked on its eastern flank. A 10-inch scope at moderate power reveals more than a dozen fainter stars.

NGC 7788 is much more scattered and roughly twice the diameter of the first cluster. Cocooned inside is a small nebulous patch. With an 8-inch scope this breaks into a tight gathering of fainter stars.

Make a straight line to the northwest about three times the separation between NGC 7790 and NGC 7788, and you'll land on King 12. Noticeable in a 3-inch refractor as a bright knot surrounded by a fuzzy glow, King 12 takes on the shape of a "dancing stickman with legs together" in a 10-inch scope at higher power.



The winter Milky Way supplies a beautiful background flow of faint pinpoints behind these clusters.

On the opposite side (southeast) of NGC 7790, Berkeley 58 appears as a granulating haze at 65x in a 12-inch scope, breaking into a few dozen faint stars at 250x. If you could see the individual stars of a dwarf galaxy, this is what they would look like.

Finally, Harvard 21 and Frolov 1 give small open clusters a bad name. If you don't recognize anything here, you're in good company, because neither of the prolific Herschels saw it. Patience and a 10-inch scope are required to obtain a satisfying view.

A computerized star atlas will be an asset if you want to see the more than 30 star clusters in Cassiopeia. Tackle the bright ones first, then wait for good conditions to sleuth out the rest.

The star pops out from behind the moon after its game of hide and seek approximately 47 minutes later. The precise time of reappearance depends on your specific location, so you should acquire accurate predictions for your observing site.

On Christmas Eve a fine occultation of Delta Cancri occurs. Delta Cancri is the magnitude 3.9 star that lies near M44, the Beehive Cluster. Even next to the waning gibbous moon, you can view the bright star with binoculars. The star reappears approximately 68 minutes later. Serious observers might try timing these events using the time signals from WWV Fort Collins (2.5, 5, 10, 15, and 20MHz SW) as a reference. You can also check the web page of the International Occultation Timing Association (IOTA) for timings of bright star occultations for major cities across the United States and instructions on making accurate observations. Links to web pages in other countries are also provided at their site (lunar-occultations.com).

This season's gala activities begin with the evening sky, which decks out in holiday style — stringing lights across the heavens as the winter constellations Orion, Taurus, and Gemini replace the dimmer autumnal constellations of Cetus, Pisces, and Andromeda. The bright festivities run into the morning hours. A brilliant magnitude –4.1 **Venus** rises around 4 A.M. local time. On December 1, Venus lies 4° northeast of Spica — a spectroscopic binary star in the constellation Virgo. Two days later, a slim crescent moon passes less than 3° north-northeast of Venus, presenting a great opportunity for the photographers among you. Over the following few weeks Venus moves quickly into Libra the Balance. Telescopically it portrays a disk illuminated 67 percent and grows to 75 percent by month's end. At the same time, the apparent size of the disk shrinks from 17" to 15".

The finest morning apparition of **Mercury** occurs this month — fresh from its transit across the face of the sun last November 15. Mercury stands high in the southeast before dawn, rising a full 1 hour, 40 minutes before the sun on December 1. It shines at a brilliant magnitude –0.5, making it quite unmistakable. A crescent moon on December 5 announces the arrival of Mercury — the crescent moon lies a mere 5° northwest of the innermost planet.

The winter solstice occurs on December 22 at 2:44 A.M. Eastern Standard Time and marks the southernmost declination of the sun for the year. The sun now begins to increase in declination, eventually providing warmth for the springtime thaw.

Martin Ratcliffe is Director of Theaters at the Exploration Place in Wichita, Kansas. Alister Ling is a meteorologist working for Environment Canada in Alberta.

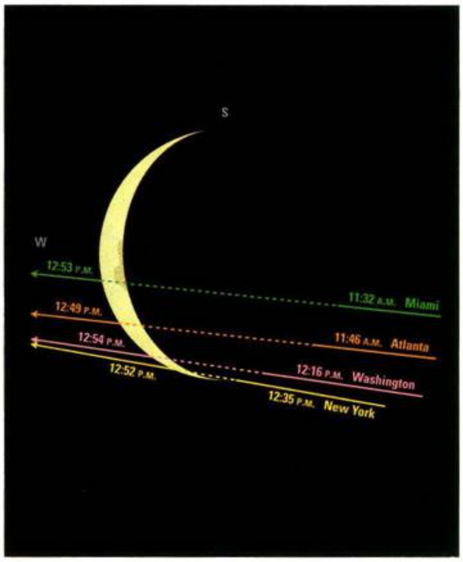
The Disappearance of Mars

Warning! This is a rare event. The next time a respectable chunk of the continental United States can watch the moon passing in front of Mars is December 2010.

Near midday on Sunday, December 12, the crescent moon covers Mars for those observers east of a line from central Minnesota to central Texas. Canadians in southern Ontario have to travel just southwest of London to find a seat, and those north of New York City will have to make their way south as well.

The waxing crescent moon will float moderately low in the east-southeast, about 50° (five fist widths at arm's length) from the sun. Use binoculars to find it first, then pop your telescope on it. While this won't be spectacular, especially given the low altitude of the moon, it will be unusual. Don't forget to scan along the moon's terminator, daylight hours will give it a new perspective.

For New Yorkers, Mars slowly disappears under the moon's dark limb just after 12:30 P.M. EST and sprouts off the sunlit north limb at about 12:50 P.M. EST. In Eastern Texas, only the reappearance can be seen, at around 11:35 A.M. CST.



Lucky observers in the British Isles, western France, and northwestern Africa can watch this event in a dark sky.

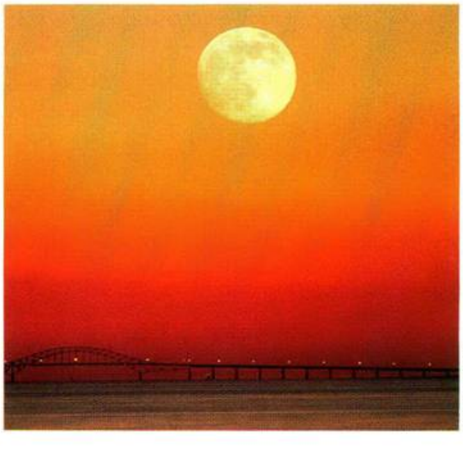
XXL Moon

Sometimes the moon appears big, and at other times, it really is big.

Many skywatchers are familiar with the "full moon illusion," which occurs when the moon is just rising. It looks huge relative to distant trees or buildings, but in a few hours when the moon rises higher in the sky, it appears to have diminished to its ordinary girth.

The moon also changes in apparent size because of its elliptical orbit around Earth, bringing it periodically closer and then swinging it farther away on its relentless pursuit of the future. On the evening of Wednesday, December 22, the moon reaches its closest point to Earth for the year (perigee), and, by lucky coincidence, it's full.

The moon will span an angular size of 33.7', about ⅒ a typical binocular field of view. In comparison, the mid-July 2000 full moon occurs at apogee, the farthest point in the moon's orbit around Earth. On that date the moon will appear to be 29.6' across, more than a 10 percent reduction in size.


Larry Landolfi

If you don't want to use photos for the comparison, stretch out your arm completely and measure the moon's size against your pinky fingernail. Make sure you write down your observations, or you may forget over the next seven months.

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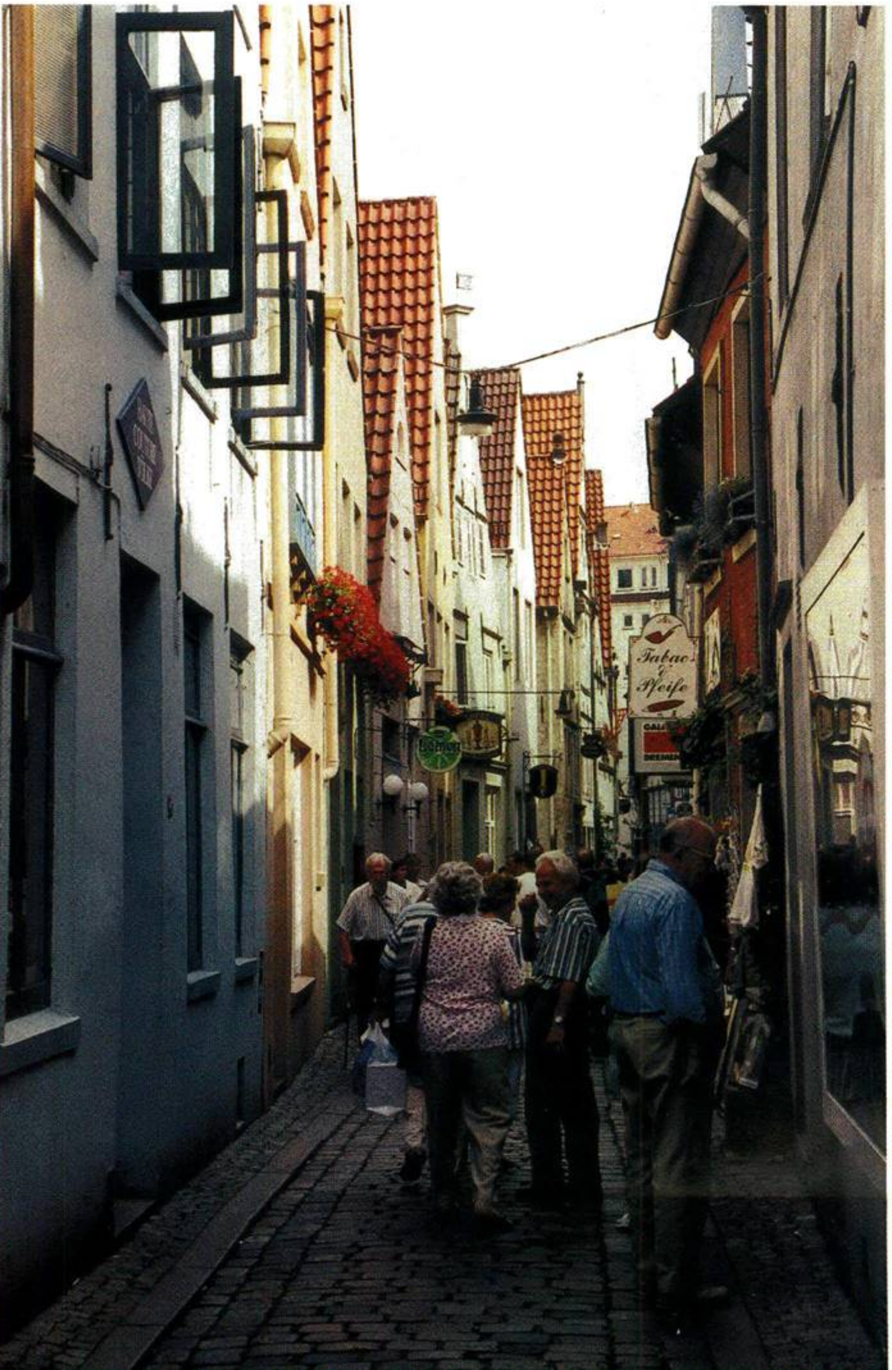
It wasn't Moses parting the Red Sea, but a sudden break in the clouds that let in totality seemed almost as miraculous.

A Partial View of Totality



Our train pulled into the Munich station right on time, reaffirming our faith in the legendary punctuality of the German rail system. My wife, Evelyn, and I were set to embark on an eight-day tour of southern Germany and Austria centered around the total solar eclipse of August 11.

We had a slight advantage over many of the 38 other people on the tour, however, having arrived in Europe two weeks earlier: Sightseeing had left us tired but not jet-lagged. As luck would have it, the skies were perfectly clear for those two weeks. But by the time we arrived in Munich, the weather had taken a turn for the worse.

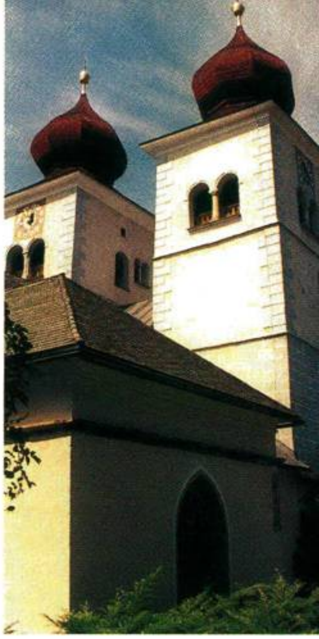
Our base of operations was the Hotel Torbräu, the oldest hotel in Munich. (Fortunately, it's been remodeled a few times in the 500 years since it opened.) From Munich, we enjoyed side trips to Neuschwanstein — King Ludwig II's fairy-tale castle — and Oberammergau, among other spots.

And all the while, the weather deteriorated. By the 10th, the rain was falling in earnest. While our group visited Munich's grand Deutsches Museum, I stole away to study live weather satellite images. It didn't look good. That evening, local forecasters were giving a 20 percent chance of seeing the eclipse, with the best prospects west of Munich.

The weather systems picked up speed overnight, however, and eclipse morning dawned clear. That was bad news — the clear spot that was supposed to be west of Munich at noon was already overhead. A few calls to the German Meteorological Service confirmed our suspicions: East was where we needed to go.

They recommended heading to Chiemsee, the largest lake in Bavaria, and we managed to find an open field just north of the lake. We set up under partly cloudy skies, but a large cloud parked itself in front of the sun as totality approached.

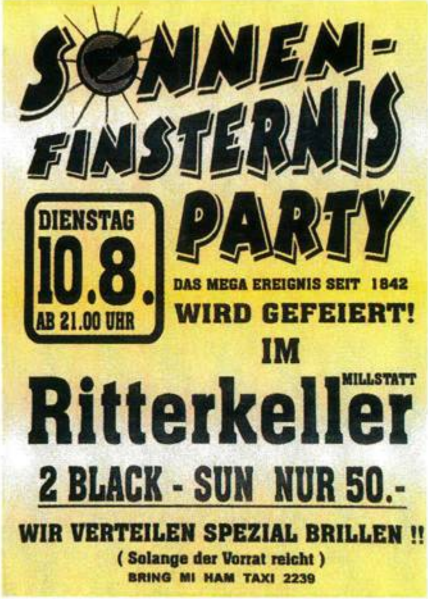
As darkness fell, we had to be content with a glorious view of twilight colors highlighting the Alps to our south. Then, without warning, the eclipsed sun appeared. Apparently the solid cloud cover consisted of two layers moving in opposite



directions, and they split at just the right time. Through high haze, we saw the inner corona, two nice prominences, and a beautiful diamond ring to close totality. Afterward, we all guessed that we had seen 10 to 20 seconds of totality, but Candace Pratt's tape recording proved we got 45 seconds' worth. We then had good views of the partially eclipsed sun before the clouds and rain returned.

The pace of the tour picked up after the eclipse as we visited three towns in three days. First up was Berchtesgaden and a trip to Hitler's Eagle's Nest. Although the peak was cloaked in dense fog, a few brief breaks hinted at the vista. Then it was on to Salzburg, Austria, birthplace of Mozart and, of nearly as much interest, physicist Christian Doppler. Finally, we visited the tiny town of Königsleiten nestled in the Austrian Alps. Fresh snow glistened on the high peaks in sunlight while night brought dark skies for stargazing. A 24-inch telescope provided exquisite views of the Whirlpool Galaxy (M51) and other deep-sky favorites, but many of us were just as impressed with the Milky Way and a slew of bright Perseid meteors.

The bus ride back to Munich signaled the end of the tour for most, but a few of us continued on to the Canary Islands. The highlight was a guided tour of the premier European observatory in the Northern Hemisphere, on La Palma. The spectacular scenery at the top of the volcanic caldera was surpassed only by our insider's look at the 4.2-meter William Herschel Telescope. After a day of relaxation, it was time to head home. The nine-hour flight gave us plenty of time to reflect on our adventures and begin planning for the African eclipse in June 2001. — *Richard Talcott*



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WIRD GEFEIERT!
IM
MILLSTATT
Ritterkeller

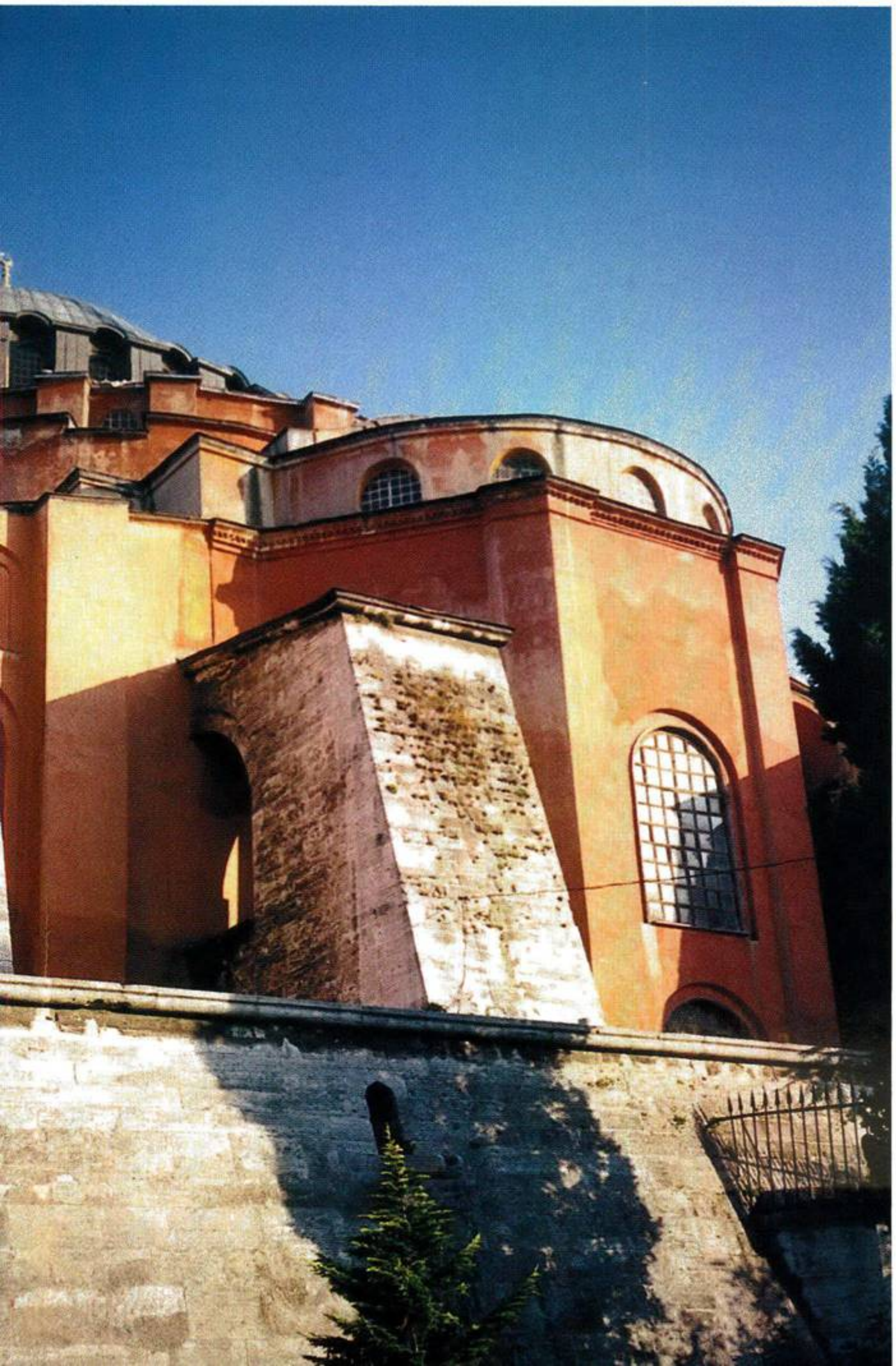
2 BLACK - SUN NUR 50.-

WIR VERTEILEN SPEZIAL BRILLEN !!
(Solange der Vorrat reicht)
BRING MI HAM TAXI 2239

Previous page: Narrow streets are the norm in crowded European cities. Clockwise from top left: The setting sun silhouettes cranes from the roof of Berlin's Reichstag; the group tours Salzburg; an Austrian church beckons tourists and worshippers; a brief break yields this view from the Eagle's Nest; hopeful eclipse chasers prepare for totality; the eclipse provided a good excuse for a party. Evelyn Talcott

A cruise through the Mediterranean and Black Sea provided the best show.

The Sun Went Down in Daytime

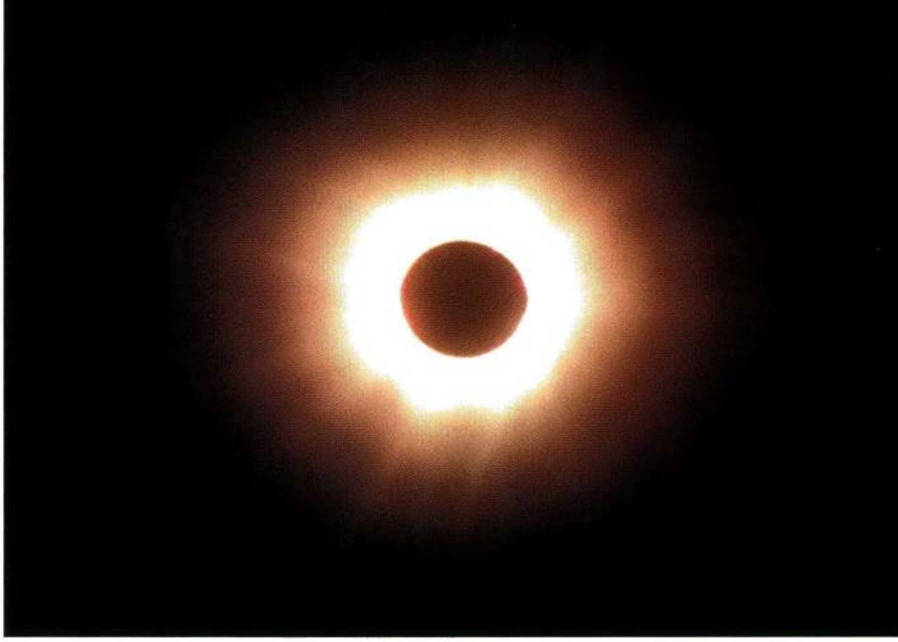


In late afternoon on August 11, we moved inside, away from the Black Sea's intense sunlight, to talk things over. A woman asked if anyone had timed the eclipse. It seemed to her much shorter than its promised 2 minutes, 20 seconds. But astronomer Bob Berman reassured her. Two awe-inspiring minutes seem to move a good deal faster than ordinary ones. About 400 people had traveled here together to watch a total eclipse of the sun; a thing that once signaled evil had brought us here for pleasure. We got what we came for — in spades. We got two diamond-ring effects, an evenly rounded corona, and a profusion of prominences.

"Too bad we have to blink," one pilgrim said. Another eclipse chaser hollered at the disappearing diamond ring "Aw, don't go away." As the sun's surface shrinks in an eclipse, the temperature falls in the path of totality and the light takes on eerie tones that send animals toward the barn and sparrows toward the trees. Charlie Byrne described the eclipsed sunlight as "fluorescent lighting." When the final diamond of our eclipse vanished and the sun gradually came out again in force, the contrast in light may have been even more startling than it was as the sun faded.

In most ways this trip was an observer's delight. The Milky Way distinguished itself in clear skies almost every night. Only in Istanbul was there competition from manufactured light. So every night after dinner and the cabaret, stargazers gathered top deck to be guided by Warren Young and Bob Berman through the summer constellations. The biggest crowd came on August 12 to watch for meteors during the Perseid shower. Sandra Young counted 79 meteors in less than an hour, but meteors were relatively rich all week long.

One disappointment only: Though we searched at sunset each night for the green flash, no one saw it from the ship. One small group of passengers claimed they had seen it on the final night of our cruise, from their table by the bay in



Mykonos in the shade of the famous windmills. I had left this group just before sunset though, and I know they had consumed a beer or two to help their vision.

Quite by accident we saw Constantsa, Romania, a Black Sea resort and shipping town. A cable broke in the Bosporus, preventing our ship's scheduled departure from Istanbul, so we couldn't make Yalta in time. We sailed instead to Romania. It turned out to be the only place along our way where travelers could buy eclipse T-shirts in the shops. We bought them all.

We sailed and walked among the minarets of Istanbul, relieved that the Kurds and Turks had signed a truce and blissfully unaware of the tragedy that would befall this exotic place shortly after we were gone. (Though we knew many of the city's 2,000 mosques have been rebuilt following earthquakes.) We shopped in the covered bazaars for pets and plants and spices and rugs.

Back in Greece, heading to Athens, we stopped at the island of Santoríni long enough to ride donkeys to the top edge of the volcanic caldera where the town Fira perches. We stopped again in the islands of Limnos and Mykonos to swim in the Aegean, adding a bit of exercise to our intellectual pursuits.

All these things are dear, but none so rare as the heavenly display that brought us to this part of the world. Marilyn McDonagh told me toward the end of our trip "I have a blank page in my journal for that day. I can't write about the eclipse yet." — *Bonnie Gordon*

Previous page: Istanbul's Hagia Sofia served as a cathedral from 537 until 1453 when it was turned into a mosque. Clockwise from top left: *Astronomy*'s eclipse cruise began with a tour of the Acropolis in Athens; a circular corona was the signature of this eclipse; Istanbul's Yeni Mosque draws a crowd at day's end; *Stella Oceanis* guests await totality; Alyssa Hammel enjoys a leisure moment; guests Jill Hunter Hensley and Pete Janssen wait for lunch.

Totality by Dave Buchla, Yeni Mosque by Dennis Stark, all others by Peter Sutter.

Traveling to Britain to see the solar eclipse was a gamble. Fortunately, the historical sites are captivating.

A Postcard from England

We left with *Astronomy*'s group of eclipse chasers in Britain on Saturday, August 7, my 38th birthday. More than 60 people climbed aboard two sparkling tour buses and headed west to Windsor Castle. (Our first foul weather commenced as rain periodically fell after 10 straight days of 80° F, crystal-clear skies, which had been deemed "bloody hot" by Londoners.) The castle was suitably large for living space, we determined, and we vowed never to leave halogen bulbs aglow after hearing the story of the fire. Then it was on to Stonehenge and finally into Bath under a drizzle and heavy fog.

The following day we had a splendid tour of William Herschel's house, pausing to absorb the molecules of history and sit in the garden where the world's greatest visual observer spotted Uranus. The Roman baths were a delight, too.

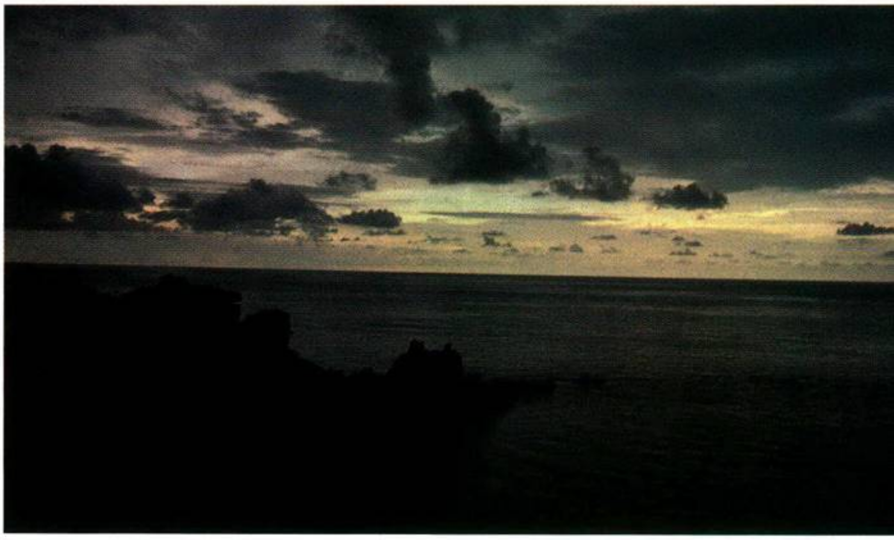
Moving rapidly south to St. Ives, a tourist colony in Cornwall, we set up shop for eclipse day. The continually sunny weather from Liverpool and London had turned continually gray, but we bravely made the hour-long bus ride down to Land's End and hoped for the best. The heavy overcast appeared to lighten briefly at an hour until first contact before the clouds thickened and shut the door on us for good. Spirits remained high as the team saw totality only through breaks in the cloud on the horizon; the eerie dusk colors and deep shadow that filtered down through the clouds made a strange experience, despite missing a direct view of the corona. I had the challenging opportunity to narrate the eclipse morning at intervals for Channel 4, ITN, grasping for positive things to say as we stood under thick clouds.

Picking up our heads the next morning, we left St. Ives and returned by rail to London — and, wouldn't you know it, under a perfectly clear-blue sky. Side trips from the great city carried us north to Cambridge, where we toured the Institute for Astronomy, heard a great lecture from Gerry Gilmore, and wandered the town. Emotional

moments were spent at Trinity College staring at Isaac Newton's quarters. We then proceeded south to Greenwich, where we stood on the Prime Meridian and toured the Meridian House and the Flamsteed House, where the first Astronomer Royal set up shop. Despite the fact that our tourists in Britain had missed the eclipse, they had a magnificent time and were happy as can be.

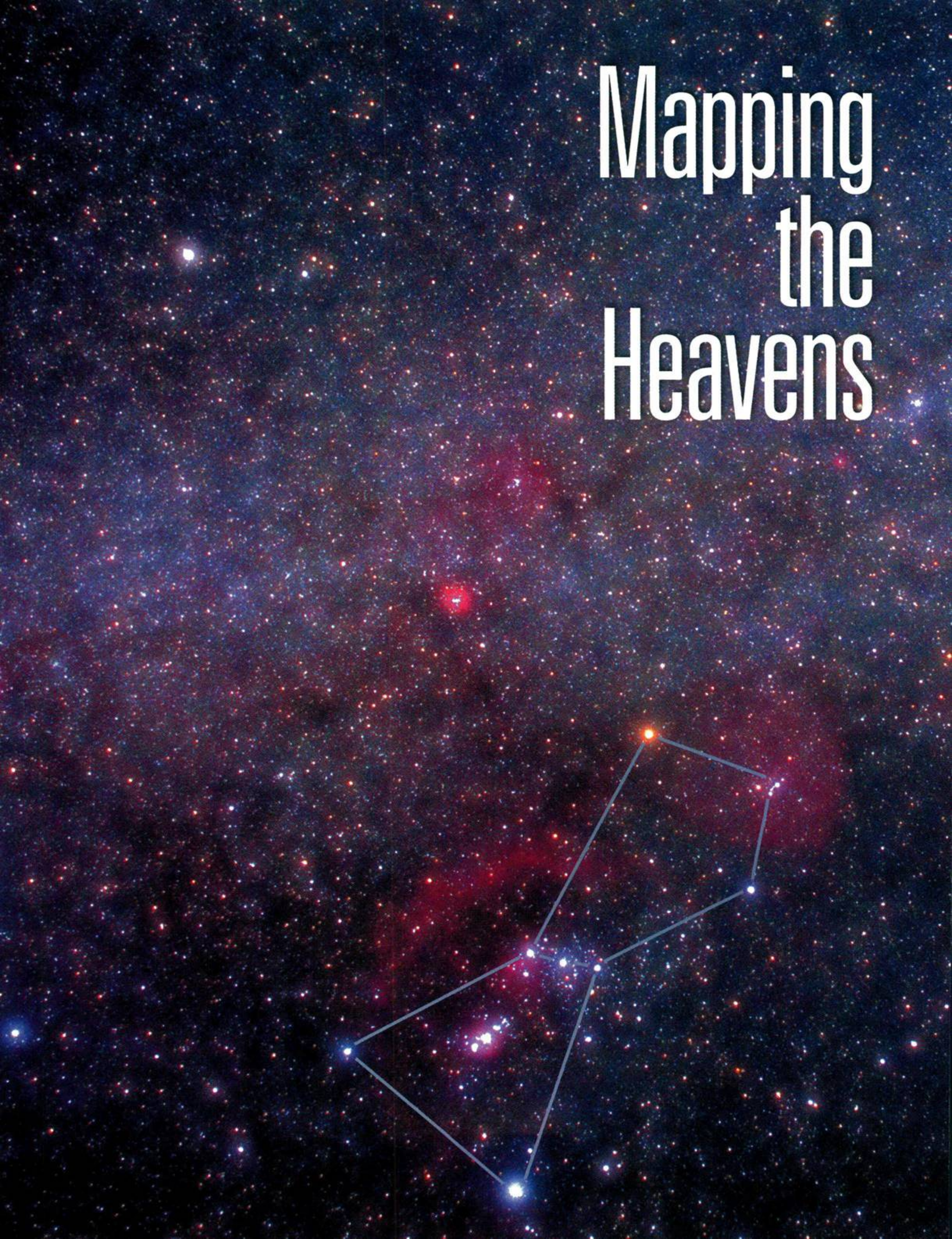
We then spent another day in London before flying back, sorry to have to ever leave. The places and the people were great, the food better than expected, and the memories will last forever. Only the weather on eclipse day let us down. I have to say, though, that I'll never understand cricket. *— Dave Eicher*

P.S. Before meeting the *Astronomy* group we spent 10 days seeing the Beatles sites in Liverpool and going nonstop, dawn-to-dusk, in London. Explored the Tower (6-year-old son Chris was fascinated with the story of the murdered princes entombed in the White Tower staircase; wife Lynda widened eyes over the Crown Jewels), Westminster Abbey, Buckingham Palace (spied the Queen Mum on her 99th birthday), the Globe Theatre, St. Paul's. Spent a whole day doing the mummies, Elgin marbles, and the Rosetta stone at the British Museum. After too much pub grub, roast beef, and Yorkshire pudding, we did the tourist thing and ate our last London dinner underneath Pete Townshend's flying V Fender at the Hard Rock. Later, saw Pete near his house in Twickenham. We'll try again in Madagascar for a clear eclipse. Long live rock!



Previous page: Big Ben stands over the Houses of Parliament. Clockwise from top left: Isaac Newton's quarters at Trinity College, Cambridge; The Beatles' Abbey Road crosswalk in St. John's Wood; the White Tower, where the murdered princes were found; totality at Land's End, Cornwall, a depressing but still ethereal sight; a Roman emperor's bust fished from the River Thames and placed in the British Museum. *Astronomy*: David J. Eicher

Mapping the Heavens



Planetarium programs offer a variety of functions for both novice and advanced observers.

by Andrea Gianopoulos

MEGASTAR
Sky Atlas for Windows
Willmann-Bell, Inc.
Data Version 4.0
This CD-ROM contains data only.
A diskette is provided for installation
of the program.
REDSHIFT 3
THESKY
Astronomy Software
2 CD
One Step
Closer to the Ideal
STARRY NIGHT
DELUXE
SOLAR SYSTEM SIMULATOR AND PLANETARIUM

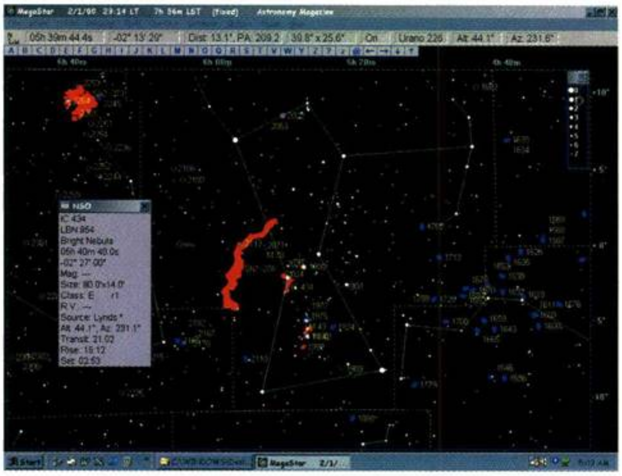
The "planetarium program" I used 20 years ago just happened to be inside a real planetarium. Through a pinhole projector, it charted the sky on a 25-foot domed ceiling. The program transported me to New Zealand, where I learned the southern constellations. It sent me to the North Pole, where I saw the sun circle above the horizon.

Now you, too, can transform a home computer into a planetarium with reasonably priced software. Four of the many applications currently available are reviewed here. Each has a variety of functions, although some may be more suitable for advanced users.

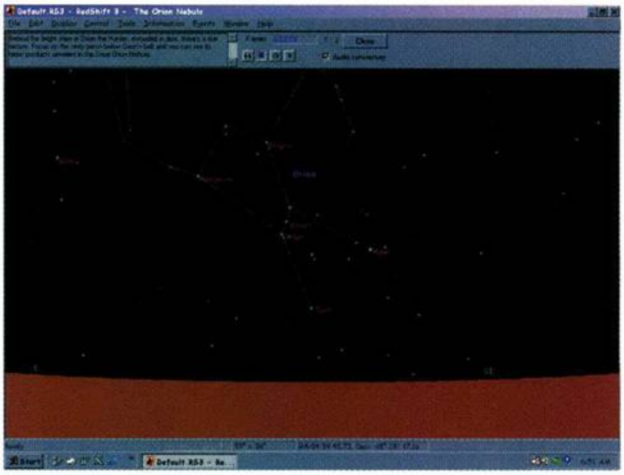
The PC versions were tested on a 450 MHz Pentium II and the Mac versions on a Power Mac 7500/100. Wide-field screen shots of the constellation Orion are found on the following pages. These should illustrate each product's display capabilities and limitations.

Deep-sky proficiency was tested by looking for a favorite of mine, Seyfert's Sextet, a galaxy cluster in the northwestern corner of Serpents Caput. All but one found and plotted this semi-obscure cluster.

Left: The best mapping programs not only feature an eloquent user interface, but they should also plot most deep-sky images on your screen. Jerry Lodriguss Right: William Zuback



MegaStar's view of Orion is colorful and loaded with useful information about a variety of astronomical objects.



Though its deep-sky views fall short, Redshift 3 provides audio commentary, QuickTime movies, and special effects.

MegaStar Sky Atlas for Windows Version 4.0

I first encountered MegaStar in 1995. A friend had just finished building a beautiful 20-inch f/5 Dobsonian and was looking for a comprehensive program to help plan observing sessions. Megastar fit the bill.

The program uses an array of databases including the *Mitchell Anonymous Catalog*, a data set of 20,000 faint, previously uncataloged galaxies developed by Houston amateur Larry Mitchell. Another useful feature incorporates corrections to existing charts and catalogs (such as *Uranometria*). The project uses Palomar Sky Survey photos to spot the inaccuracies. Finally, Megastar is also one of three programs tested here that will import additional data sets, a handy tool for finding the most obscure objects.

The use and cross-referencing of data is Megastar's primary selling point. However, I found the user interface to be less elegant than other programs. Even so, some features did entice me. The most convenient was the ability to zoom in on an object. No need to find a toolbar icon or hot key to activate the zoom. Just left click and drag to create a box around a region of sky and MegaStar zooms in. A subsequent right click centers the field on your screen.

Willmann-Bell, P.O. Box 35025, Richmond, Virginia 23235; phone, (804) 320-7016; fax, (804) 272-5920; website, www.willbell.com.

Redshift 3 Version 3.0

If you are looking for glitz and glamour, Redshift delivers both. The program's 16-bit graphics, QuickTime movies, 3-D models, and animation provide realism and punch. If you have young, budding stargazers in your midst, Redshift should hold their attention with its sophisticated graphics.

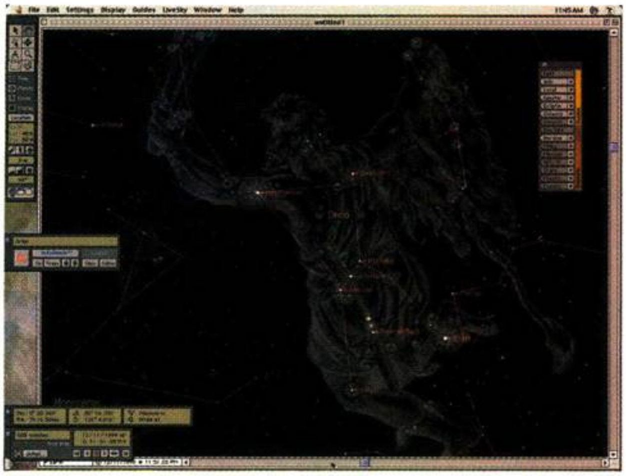
The program's explanatory QuickTime movies include such titles as: "From the Big Bang to Galaxies," "The Milky Way Galaxy," "Lives of the Stars," "The Sun," and "History of the Solar System." While its graphics draw you in, the *Penguin Dictionary of Astronomy* answers most questions. Redshift also holds a Sky Diary that displays conjunctions, moon phases, and other events.

An interesting feature called Record Breakers finds information on the hottest planet, most-observed comet,

Program Name	Version	Price	Processor	Operating System	Hard Drive	RAM	Display	Stars	Deep-Sky Objects	Databases	Import Database	Test Version	Telescope Interface
MegaStar	4.0	$129.95	PC (486)	Windows 3.1, 95, 98, NT	5MB	4MB	VGA	15 million	110,000	GSC, H/T, PPM, SAO, YBSC	yes	www.willbell.com	LX200, NGC-MAX, & Sky Commander
Redshift	3.0	$49.95	PC (Pent 100)	Windows 95, 98	5MB	16MB	color	250,000	40,000	HD, H/T, YBSC	no	no	no
		$49.95	PowerMac 90	System 7.1	5MB	16MB	color	250,000	40,000		no	no	no
The Sky III	5.0	$199	PC (Pentium)	Windows 95, 98, NT	40MB	8MB	color	15 million	87,500	GSC, HD, H/T, PPM, SAO, YBSC	yes	no	too numerous to list
		$129	PowerMac	System 8.0	40MB	16MB	color	15 million	87,500	GSC, HD, H/T, PPM, SAO, YBSC	yes	no	too numerous to list
Starry Night	2.12	$89.95	PC (Pentium)	Windows 95, 98, NT	40MB	8MB	SVGA	15 million	13,000	GSC, SAO	yes	www.siennasoft.com	LX200
Deluxe	2.13	$89.95	Mac	System 7	40MB	8MB	color	15 million	13,000	GSC, SAO	yes	www.siennasoft.com	LX200 & Ultima 2000

Hard drive refers to the amount of space needed to store program components on your hard drive.
RAM refers to the amount of Random Access Memory needed to run the program.
Import Database: Will the software package allow you to import an external database?
Test Version: Two of the packages have a downloadable test version at their website.

GSC: Hubble Guide Star Catalog
HD: Henry Draper Catalog
H/T: Hipparcos/Tycho
PPM: Positions and Proper Motions
SAO: Smithsonian Astrophysical Observatory
YBSC: Yale Bright Star Catalog



Starry Night Deluxe is an elegant program that offers slick graphics, deep-sky delights, and tasty morsels for educators.

nearest galaxy, brightest nova, and more. It's an enjoyable segment that will delight trivia buffs.

Though the graphics and added features are impressive, Redshift will leave avid deep-sky observers wanting more. Basic data on a given galaxy's magnitude and position are not displayed. It also was the only program of the four that did not locate Seyfert's Sextet on the sky chart, though its dictionary provides a definition. Redshift may be a fun program for the budding astronomer, but those seeking a tool to aid their observing will be disappointed.

Piranha Interactive, 1839 West Drake, Suite B, Tempe, Arizona 85283; phone, (602) 491-0500; fax, (602) 491-8990; website, www.piranhainteractive.com.

Starry Night Deluxe Version 2.13

This realistic program "wowed" me with a variety of features, including a comet ride to the inner solar system and the ability to watch an eclipse from the sun, moon, or Earth. You can also observe the sky from any location on any planet or large moon in the solar system.

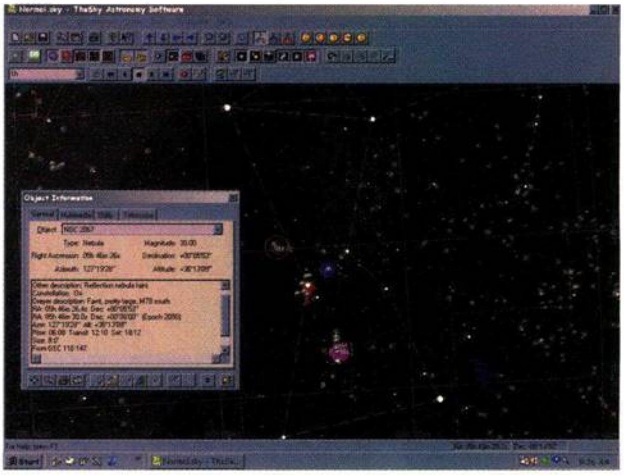
Educators will appreciate Starry Night's explanations and graphics as well as its ancillary features. One of the most impressive is the movie-making tool. It allows users to record a QuickTime movie of any event and play it back in sequence. A teacher might explain a gravity assist with a movie of a satellite flyby.

Deep-sky observers will find Starry Night handy as well. It zooms in on a region of sky while loading a Palomar Sky Survey photo to provide a detailed view. Starry Night was able to find Seyfert's Sextet (even at a close zoom), but it didn't show the orientation of each component galaxy.

From its high-quality, textured maps of the planets to its QuickTime movie-making tool, Starry Night delivers a comprehensive software package for both the novice and expert.

Starry Night Pro was unavailable when this review was written. Look for a description of this latest installment in an upcoming issue of *Astronomy*.

Sienna Software, 411 Richmond Street East, Suite 303, Toronto, Ontario, Canada, M5A 3S5; phone, (416) 410-0259; fax, (416) 410-0359; orders, (800) 252-5417; e-mail, contact@siennasoft.com; website, www.siennasoft.com.



The Sky III's free-rotate tool allows observers to create maps that suit individual needs.

The Sky III Version 5.0

This is the most powerful piece of astronomical software I have found for amateur astronomers. A bold statement, yes, but The Sky lives up to such praise. Its user interface is elegant and easy to operate, while its flexibility provides the observer with a very powerful tool.

Features include the ability to invert the display to simulate the sky as it would appear though a telescope, viewing the sky from 4712 B.C. to A.D. 10000, and a bull's-eye overlay that indicates the user-designated field of view. Another useful feature is the free-rotate tool. It allowed me to turn charts in any direction: I could place north at the top, bottom, side, or in between. This is invaluable when creating star-hopping charts. Like MegaStar, The Sky also offers a wide variety of data on any given object with a click of the mouse, and it, too, imports new databases and calculates the position angle and distance between two objects.

The Sky not only uses a wide variety of databases to plot its charts, but it also can guide your telescope. Once interfaced and calibrated with a telescope mount's digital encoders, you can move your telescope and the computer's cursor will follow on the screen. I was amazed to find the object in the eyepiece every time.

What makes The Sky stand above other programs offering telescope interfaces? Versatility. Unlike its many counterparts, The Sky can interface with a wide variety of digital encoders and computer controllers. These not only include the LX200, Ultima 2000, and Sky Commander, but also Compustar, Coordinate III, and others.

Those who want a fully automated robo-scope can purchase The Sky Level IV and The Sky Astronomy Suite. The optional programs, which I didn't test for this review, will turn your telescope into a fully automated instrument that can do CCD imaging while you lounge nearby (see "Standing Steady," December 1998). A fully automated system comes at a price. The Sky Level IV's is $249, which is not unreasonable by today's standards.

Software Bisque, 912 Twelfth St., Suite A, Golden, Colorado 80401; phone, (800) 843-7599; fax, (303) 278-0045; e-mail, thomasb@bisque.com; website, www.bisque.com. **A**

Associate editor Andrea Gianopoulos is a confessed computer nerd.

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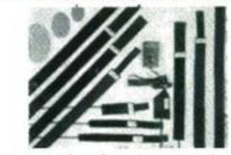

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SHOOT THE MOON IN SHADOW

by Phil Harrington

Grab your camera and some warm clothing: It's time to photograph an eclipsed moon. On the night of January 20/21, the moon slips through Earth's shadow, creating the first total lunar eclipse in nearly three years. Capturing the event for posterity is a challenge for astro-imagers. From start to finish, the moon's disk goes through innumerable changes. The full moon's radiance will diminish from magnitude –12.7 to between magnitude 0 and 4, a brightness factor of about 5 million times from onset to mideclipse. To photograph the full dynamic range, astro-imagers must have the proper equipment and be flexible enough to adapt to the moon's changing brightness. With a little planning and patience, you too can produce good photos.

CHOOSING A CAMERA

Almost any camera (with the exception of fully automatic, point-and-shoot models) will let you photograph some aspect of a lunar eclipse. Most astrophotographers prefer a 35mm single-lens reflex (SLR) camera because it offers a wider variety of auxiliary lenses and attachments. Unfortunately, most of today's SLRs feature automated everything, including exposure, focus, and flash. From an astrophotographer's point of view, these advances are detrimental. If possible, use a fully manual camera or one that has a manual override.

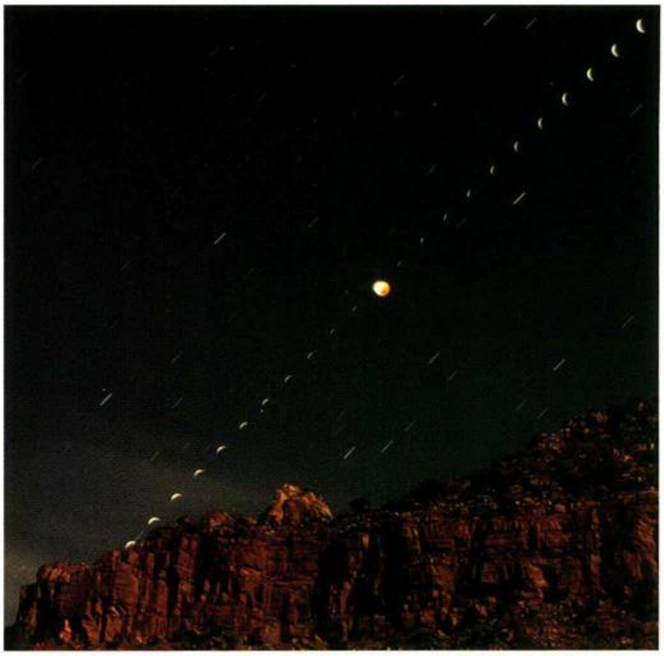
Which lens you choose is just as important as the camera. Different lenses can be used to record different aspects of the lunar eclipse. Not surprisingly, most eclipse photographers prefer to use telephoto lenses and telescopes. When coupled with a 35mm camera, a 400mm telephoto lens is roughly equivalent to the view through a pair of 7x binoculars. This combination yields the shortest focal length capable of recording any appreciable detail on the moon's surface. However, longer focal lengths, such as those through telescopes, achieve greater resolution of lunar features.

That doesn't mean shorter lenses are useless for lunar eclipse photography. In fact, you may have interesting results with short telephoto lenses and even normal-to-wide-angle lenses (55mm to 28mm). Many photographers use them to capture the totally eclipsed moon nestled among the surrounding stars and planets. This type of image is easy to take: Point the tripod-mounted camera toward the moon, compose the frame to include sky objects of interest, and shoot. Be sure to make a long exposure that captures the surrounding fainter stars.

These same lenses are also perfect for multiple-exposure sequences that record the entire eclipse on one frame. Unfortunately, few modern 35mm cameras can take multiple exposures. You can fool some nonmotor-driven cameras by pressing the film-spool-release button (usually found on the bottom of the camera's body) while holding the film-rewind knob and advancing the film.

Finally, shorter focal-length lenses are great for "moon trails." Position the moon along the eastern side of the frame so that it will creep across the photograph as it moves in the sky. Close down the camera lens to its smallest f/stop and set the shutter to "bulb." With a locking cable release in place, start the exposure by depressing and locking the release's plunger. By keeping the shutter open throughout the eclipse, the moon's image will appear to narrow, then broaden as it travels through Earth's shadow.

The moon's changing brightness during an eclipse makes determining exposure rates a challenge. Patience and a bit of forethought will help insure a pleasing outcome. Craig T. Stillwell



This multiple-exposure sequence was taken in Zion National Park during the March 23, 1997, eclipse. Jerry Schad

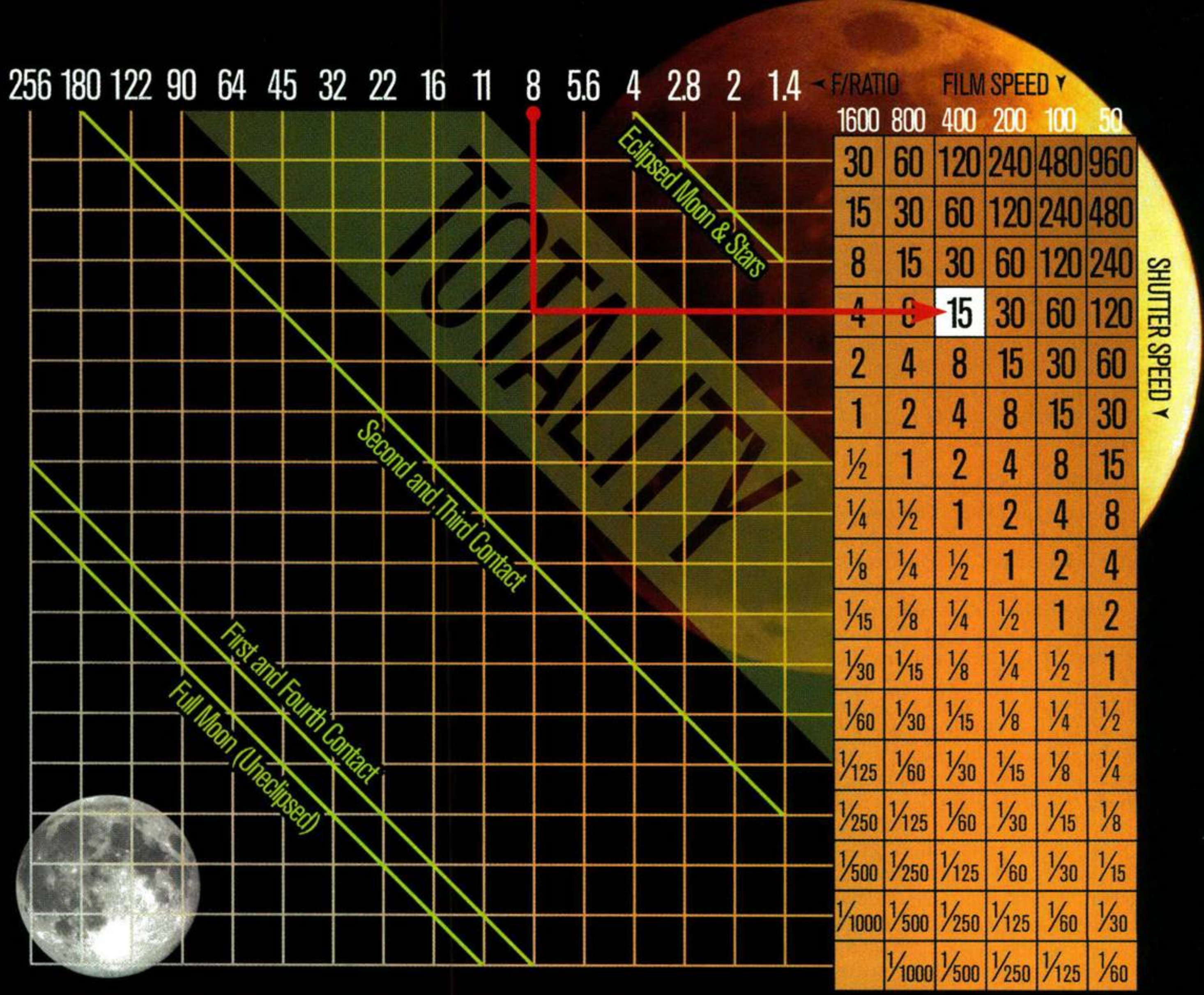
You might capture another beautiful type of lunar-eclipse sequence with a moderate telephoto lens (100mm to 400mm), what I call a "shadow sequence." The shadow sequence is a multiple exposure on a single frame of film. For this image, the camera rests on a telescope mount that tracks the stars, rather than the moon. The result is an image of the moon at several discrete stages in its silent journey through Earth's shadow. Guide the telescope on a star in the telescope's field of view (preferably using an eyepiece with crosshairs). Don't be concerned if the star shifts within, or even leaves, the field of view; just make certain it's always centered for each exposure.

It's important to plan the number and times of all exposures accordingly. This gives the final multiple-exposure image symmetry. To achieve this, you'll want to take a photograph around mideclipse. Plan the timing of other exposures at even intervals before and after the midpoint.

If you photograph the eclipse through a telescope, first choose the method by which the camera will be attached to the instrument. Most photographers prefer the "prime focus" setup in which the camera body alone, with no lens, attaches directly to a telescope in the focal plane where the eyepiece goes. The "afocal" method aims the camera and its lens through the telescope's eyepiece itself. This process can introduce optical aberrations that will degrade the image. It's also easy to figure the f/stop of your camera-telescope combination with a prime-focus setup. Simply use the telescope's focal ratio (f/number).

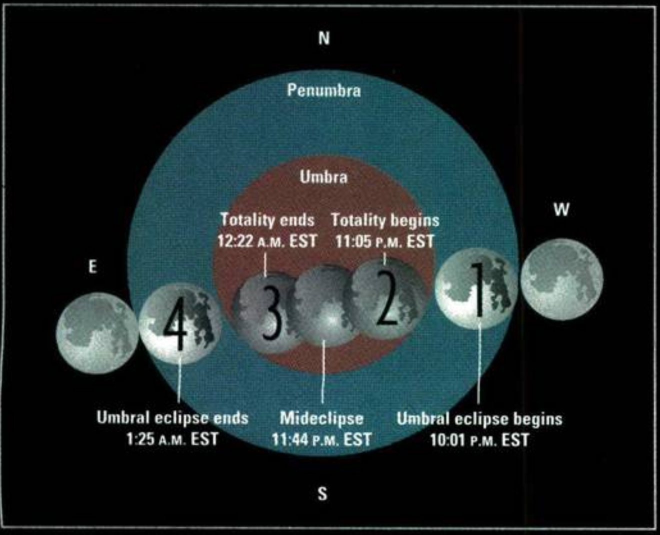
THE FACETS OF FILM

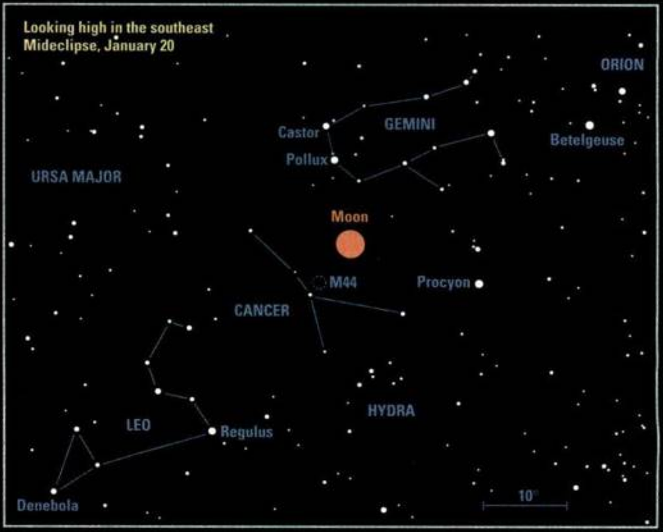
With camera and lens set, consider film choices. Almost any will do for photographing the uneclipsed full moon. But remember, the moon's light will be considerably diminished during totality. Therefore, unless you track the moon with a properly aligned, clock-driven equatorial mount, you should stick with high-speed (ISO 400 and greater) films. They



1600	800	400	200	100	50
30	60	120	240	480	960
15	30	60	120	240	480
8	15	30	60	120	240
4	8	15	30	60	120
2	4	8	15	30	60
1	2	4	8	15	30
½	1	2	4	8	15
¼	½	1	2	4	8
⅛	¼	½	1	2	4
1/15	⅛	¼	½	1	2
1/30	1/15	⅛	¼	½	1
1/60	1/30	1/15	⅛	¼	½
1/125	1/60	1/30	1/15	⅛	¼
1/250	1/125	1/60	1/30	1/15	⅛
1/500	1/250	1/125	1/60	1/30	1/15
1/1000	1/500	1/250	1/125	1/60	1/30
	1/1000	1/500	1/250	1/125	1/60

SHOOTING THE LUNAR ECLIPSE: The table's top, right-hand side denotes ISO film speeds. The columns offer corresponding shutter speeds in seconds. The numbers along the top left-hand side of the table represent the focal ratios (f/stops) of various camera lenses or camera/telescope combinations. The series of diagonal lines are labeled with different stages of the lunar eclipse. The contact points refer to the moon's location within Earth's shadow: 1, first contact with the umbra; 2, totality begins; 3, totality ends; 4, last contact with the umbra. Earth's umbral shadow varies in darkness from eclipse to eclipse, so values at mideclipse can vary greatly depending on how dark that shadow makes the moon appear.


N
Penumbra
Umbra
Totality ends
12:22 A.M. EST
Totality begins
11:05 P.M. EST
W
E
4
3
2
1
Umbral eclipse ends
1:25 A.M. EST
Mideclipse
11:44 P.M. EST
Umbral eclipse begins
10:01 P.M. EST
S


Looking high in the southeast
Mideclipse, January 20
ORION
Betelgeuse
Castor
Pollux
GEMINI
URSA MAJOR
Moon
M44
Procyon
CANCER
HYDRA
LEO
Regulus
Denebola
10°

permit shorter exposures that limit blurring of the moon's image due to Earth's rotation.

Will slide or print films work best? Both have their merits. Slide film eliminates one critical step, printing. Print film, however, offers a wider margin for error. Photographers often refer to this margin as a film's "forgiveness factor." Here, color-negative film wins handily over slide film. Even slightly over- or underexposed color negatives can produce acceptable color prints, given a skilled darkroom technician. On the down side, poor finishing can turn a first-rate negative into a muddy, ill-focused, improperly exposed print.

Some print films to consider include Fujicolor Superia 100, 200, or 400; Professional 400 NPH; NHG II 800; Super G Plus 800; Kodak's Royal Gold 100, 200, or 400; or Gold MAX 100, 200, or 400. Good slide film choices include Kodak Elite Chrome 100, 200, and 400; Kodachrome 200; Fujichrome Sensia II 100, 200, and 400; or Fujichrome MS 100/1000 Professional.

After the camera and film, you need a cable release (with a locking thumbscrew for moon trails) and a mount for the camera. If you intend to photograph the moon with a camera and lens alone, pick up a sturdily constructed camera tripod. Those shooting through a telescope need to make certain that the telescope's mount can handle the camera's extra weight. If your telescope mount is a little shaky, hang a plastic gallon jug of water from the center of the tripod. This usually makes the tripod solid enough for short exposures of the moon. Even a telescope on a Dobsonian mount can be used to photograph the brighter, partial phases of the eclipse. Just make sure the camera's weight is counterbalanced properly. Having said all that, be aware that a properly aligned, clock-driven equatorial mount is a must for all but wide-field shots of the moon during the total phase of the eclipse.

SHOOT IN STYLE

With the equipment set, consider technique. Every experienced astro-imager has taken some shots that were perfectly composed, meticulously exposed, but completely worthless because of improper focusing. Here's an easy way to get sharply focused images of the moon the first time and every time. Cut out a piece of cardboard the same diameter as the telescope's (or lens's) aperture. In the mask, cut two smaller circles directly opposite each other from the mask's center. Cut 1-inch holes if your telescope has an aperture of 6 inches or less, or 2-inch holes for telescopes 8 inches and larger. With a reflector or catadioptric telescope, make certain that the holes are not blocked by the instrument's secondary mirror.

Attach the mask to the front of the telescope, mount the camera, aim it at the moon, and look through the camera's viewfinder. If the telescope is out of focus, you'll see two overlapping images. Turn the focusing knob in or out until the two images merge into one. When you see a single image, the telescope is properly focused. Once the focus is set, mark that point on the instrument's drawtube or barrel so the focus setting can be easily repeated. If you're looking for a commercial version of this device, Jim Kendrick Studio (2775 Dundas St. West, Toronto, Ontario M6P 1Y4; http://www.kendrick-studio.com) sells a three-hole version called Kwik Focus.

After focusing sharply, the concern shifts to exposure. The number of variables, such as local sky conditions, altitude of the moon, and opaqueness of Earth's shadow during the eclipse, makes determining an absolutely "correct" exposure nearly impossible. However, the chart on the facing page can offer a few suggested exposures and f/stop settings.

Eclipsed Moon: Pierre Guillermier, Full Moon: John Bucce, Illustrations *Astronomy*: Elisabeth Rowan

The eclipsing moon and Saturn trail over Mexico's Baja Peninsula. This two-hour exposure was taken on September 26, 1996. Alejandro Gastelum

Let's say you want to capture the totally eclipsed moon with an f/8 lens or telescope and ISO 400 film (follow the red line on the chart). First, remember that f/8 is f/8 regardless of the telescope's or lens's aperture. (Don't worry if your f-ratio is not listed precisely on the chart, choose the closest value.) Look for the "8" along the top left-hand side of the table and follow the vertical line until you come to the area labeled "totality." Turn right and trace the horizontal line from that intersection into the chart's right-hand portion. Find the point where the ISO 400 column and the horizontal line meet. This example gives a suggested shutter speed of 15 seconds.

The broad range of values given for totality depend on the darkness of Earth's umbral shadow. Because this range is large, it pays to take several photos at different exposures with the hope that a few will come out well. The totality range for an f/8 instrument using ISO 400 film is 120 to 2 seconds. In this example, start taking images with two-second exposures and double the rate on each subsequent frame. The chart is meant as a guide to begin your exposures. Don't be afraid to bracket them up and down by one or two f/stops from these recommendations. Remember, the more images you take, the better your chances are of shooting that ultimate exposure.

To make eclipse photography easier, write down the details ahead of time. Record the frame number, time, film, exposure, and f/stop. Fill in each value before the eclipse, remembering to bracket exposures by one or more f/stops. When you get the photos back and see which turned out well, you can replicate them easily the next time.

The January lunar eclipse is sure to be one of the premiere celestial events of this, the final year of the 20th century. Plan ahead so you can show off those wonderful photographs well into the next millennium.

Phil Harrington is a frequent contributor to Astronomy. *You can learn more about eclipses from his book* Eclipse! *or visit his website at http://ourworld.compuserve.com/homepages/pharrington.*

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10"f/4.5 Dobsonian Starfinder ($85P&S)	$599
10"f/4.5 Equatorial Starfinder ($99 P&S)	$879
12.5"f/4.8 Dobsonian Starfinder ($95P&S)	$895
16"f/4.5 Dobsonian Starfinder (frt. COD)	$1195
16"f/4.5 Equatorial Starfinder (frt. COD)	$2695

*All Starfinder telescopes shipped directly from Meade to the purchaser. Please add the indicated packing and shipping charge to the price. Slightly lower P&S for payment by check. Lumicon showroom prices are $50 to $100 higher.

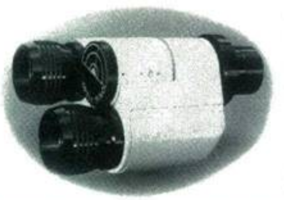
See the Meade ad in this magazine for full descriptions. Starfinders are complete telescope systems with motor drive and finderscope (Equatorial only) and 25mm (48x) eyepiece. New DC motor runs on four AA batteries.

MEADE® Dobsonian Starfinders

ACCESSORIES

Magellan computer, specify Dob or Equatorial ($15 P&S) $285; **Lumicon 1 1/4" UHC or O-III** Filter $99.50. **Vinyl covers** to keep dust free (2 req.) for **6" - $10**; for **8" - $15**; for **10" - $20**; for **16" -$35**.

New LUMICON® binocular viewer



The new LUMICON Binocular viewer is judged to be equal or superior to even more expensive binoviewers. Custom made for Lumicon , these exquisite German-made units have the highest image transmission (91%) Threaded for filters. Both planetary and deep-sky viewers will be impressed. **SALE PRICE 'til Dec. 31 $649 00**

3X apochromatic relay lens for Newtonians **85.00**

Adjustable piggyback mount

LUMICON's piggyback mount is ideal for telescopes of 6-16" aperture. It permits both vertical and sideways adjustment for optical alignment. Also ideal to mount LUMICON 80mm SUPER-FINDER, large telephoto lenses and small telescopes up to about 5 lbs.

Lumicon Adj.Piggyback Mount $59.50

Specify telescope size: 6", 8", 10", 11", 14", 16";

H-ALPHA pass filter

Yields spectacular contrast gains in B&W photography with telephoto lenses. Yields pinpoint star images. Superb with hypered 2415. For color, use the LUMICON Deep-Sky (DS) filter.

Specify Lens Size	H-Alpha	DS
46,48,49mm	$59.00	$199.50
52,55,58,62mm	$69.00	$199.50
67,72,77mm	$79.00	$399.50
82mm (77mm+adapter)	$89.00	$415.00
Hypered 2415 film, 36 exp		$13.95

Lots of Adapters

2" adapter for C-8 Meade 2080, etc.	$29.50
2" adapter for C-80, C-102 refractor	$39.50
2" adapter for C-70, C-80F, C-102F fluorite	$39.50
2" adapter for C-6, Comet Catcher, Meade 395	$30.00

Extension Tubes

1" long 1 1/4" OD thread-in extension	$12.00
2 1/2" long extension (holds 1 1/4" filters)	$19.50
4 1/2" long extension for 1 1/4" eyepieces	$29.00
3" long extension for 2" eyepieces*	$29.00
2" long extension for 2" eyepieces*	$29.00

Viewing Adapters

2"\1 1/4" reducing bushing, thread 48mm*	$25.00
2" T-thread adapter, threaded 48mm*	$25.00
T-thread 1 1/4" adapter	$25.00
F/10 2" or 1 1/4" eyepiece viewing adapter for Giant Easy-Guider	$59.50
Low profile star diagonal eyepiece holder	$16.00
Meade 2" diagonal /Giant Easy-Guider	$39.50

**threaded to hold 48mm filters*

Meade SCT & Maks 3.5"-16"

ETX w/electronic control ($20)	$595
ETX Auto Star computer controller	$155
8"LX10 w/wedge, hand controller ($65)	$995
Field Tripod for 8" LX10 ($20 P&S)	$195
8" LX50 w/wedge ($115 P&S)	$1395
Adj. tripod for 8-10" SCT ($30 P&S)	$295
8" LX200 w/computer ($65 P&S)	$2795
Wedge for photographing w/8" LX200	$139
7" LX50 f/15 Maksutov w/wedge ($125 P&S)	$1795
10" LX50 f/10 w/wedge, dec. motor, hand controller ($155 P&S)	$1695
10" LX 200 w/ computer ($155 P&S)	$3195
12" LX 200 (f/10 only) ($215 P&S)	$4495
SuperWedge for photo. w/10", 12" LX200	$395
16" LX200 f/10 w/tripod ($385 P&S)	$14,950

LX50 – includes dec. motor, hand controller.
LX 200 - full computer control w/64k mem.
Tripod: Extra for LX 50; included for LX200

Note: Wedge is not needed for visual observing with the LX 200. Select f/10 or f/6.3 (no extra charge) for LX 200.

PHOTOGRAPHY ACCESSORIES

Cassegrain Easy-Guider 4"-8" f/6 or f/10	$249
Giant Easy-Guider for 10"/12" f/4-f/10	$395

Dew Shields				
	8"	$119	10"	$129
	12"	$189	16"	$289

Takahashi

Telescopes and accessories. 10% off! Call for details

Low Profile Focusers

Select your desired base plate shape: Coulter Odyssey (thread on installation), Flat 7",9 1/2"OD, 12 1/2"OD, 16"OD, 21"OD.

Lumicon 1 1/4" Helical Focuser	$69.50
Lumicon 2" Helical Focuser (1 1/2" high)	$85.00
2" Astro systems focuser (only 2"high)	$149.00
2"/1 1/4" adapter w/48mm filter threads	$25.00
2" LUMICON Easy-Guider™	$189.50

LED flashlight $14.95

This red LED flashlight preserves night vision. 2 AA cells (incl.) will last 60 to 100 hours.

Lumilite™ red LED flashlight	$14.95
Starlite™ adjustible red LED flashlight	$24.95
Skylite™ adjustible white/red LED	$29.95
Kuikfinder 1X reflex finder	$39.95

Large UV/Dust Seal

Protect the optics of your 8-14" Schmidt-Cassegrain with a UV/Dust Seal. A/R Coated.

Deep-Sky filter/dust seal for C-8, 2080	$199.50
UV/Dust Seal for Celestron 5"-9"	$39.00
UV/Dust Seal for Meade 4"-8"	$39.00
UV/Dust Seal (lg.) for Meade 10"-12"	$89.50
UV/Dust Seal for Celestron 11"-14"	$89.50

Solar Prominence Filters

Lumicon Solar Prominence Filter 1 1/2" Angstrom bandpass. Includes 77mm energy rejection pre-filter. (State telescope type) $595

3" off-axis metal mask to hold pre-filter ..... 8"SCT, $68; 10", $88; C-11, $88; C-14, $110

2" adapter for C-8. Meade 8-12" $29.50

Adapter for 1 1/4" or .096" focuser $22

EYEPIECES

Great Prices ! Pentax 65° XL

Amazing performance! All have 20mm eye relief, adjustable helical eye guard, super multi-coatings, E.D. Glass

5.2mmF.L., 65°Apparent Field 1 1/4"	$279
7mm F.L., 65° Apparent Field 1 1/4"	$279
10.5mmF.L., 65°Apparent Field 1 1/4"	$269
14mm F.L., 65° Apparent Field 1 1/4"	$269
21mmF.L., 65°Apparent Field 1 1/4"	$269
28mm F.L., 55° Apparent Field 1 1/4"	$259
40mmF.L., 65°Apparent Field 2"	$299
Pentax orthos available (ea.)	$159

Tele-Vue

4X Powermate for 2" eyepieces	$265
5X Powermate boosts magnification 5x	$168
Ranger 70mm f6.8 apchromat w/45° diag.	$685
Pronto 70mmf6.8 w/45° erecting prism	$925
Tele-Vue 85,85mm f/7 APO telescope	$1995
Bino-Vue binocular w/2x correc.	$1030
Gibraltar mount with ash wood tripod	$530
8,11,15mm Plossl . $82 — **20,25mm**	$95
32mm Plossl, widest true field in 1 1/4"	$110
55mm Plossl, widest possible field	$230
2.0x or 3.0x Tele Vue Barlow Lens	$105
2" Giant Barlow – 2x	$168
4.8mm Nagler 82° field, 1 1/4 " eyepiece	$175
7mm Nagler, 1 1/4 " eyepiece, 82° field	$220
9mm Nagler, 82° field 1 1/4 " or 2"	$240
12mm Nagler Type 4, 82° 1 1/4 "or 2"	$340
16mm Nagler Type II, 82° 1 1/4 "or 2"	$310
17mm Nagler Type 4, 82° 1 1/4 "or 2"	$370
22mm Nagler Type 4, 82° 2" only	$445
2" Paracorr visual coma corrector	$235
3,4,6,8,10,14mm Radian,60° field	$228
15mm Panoptic 1 1/4", 68° field	$210
19mm Panoptic 1 1/4", 68° field	$240
22mm Panoptic 1 1/4"/2", 68° field	$280
27mm Panoptic 2", 68° field	$330
35mm Panoptic 2", 68° field	$365

Note: TeleVue warranty may not be valid outside USA

Dust Covers

Protect your valuable telescope optics eyepieces and accessories with these black vinyl covers. Add $1 shipping. Deduct 10% for 2 or more sets.

1 1/4" O.D. plug, seals focuser ..... 4/$2

2" O.D. plug	2/$2	3 1/2" O.D. plug	$1.50
1 1/4", 1 3/8"	3/$2	7 1/2"	$10
1 1/2"	2/$2	9 1/2", 10.4"*	$15
2"	2/$2	12 1/2",12 7/8"*	$20
2 1/8"	2/$2	15", 15.6", 16"*	$28
5 1/2"	$6	19" (DS-16)	$35
*Fits Odyssey		21" (Odyssey-II)	$35

LUMICON

2111 Research Dr. #4-5, Livermore, CA 94550
Phone Orders: Call our toll free order line: 1-800-767-9576
EXPERT Information: Call 1-925-447-9570
FAX 1-925-447-9589 ▪ Write for FREE Lumicon products catalog

Telescopes and Accessories

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1-800-767-9576

2111 Research Drive, Suite 4-5, Livermore CA 94550 ▪ Phone hours: M-F 9AM/5PM pst Sat. 9AM/1PM

Lumicon 50mm & 80mm SUPER FINDER

Visual astronomers prefer the **LUMICON 80mm Super-Finder™,** since hundreds of deep-sky objects, including most Messier objects, are visible directly. Super-Finders™ also make nice small portable telescopes. 80mm aperture, F=300mm coated achromat: or 50mm, F=200mm coated achromat. Eyepieces and/or star diagonal are extra.

1¼" **50mm** finderscope or 45° version	$69.50
1¼" **straight-thru 80mm** superfinder	$199.50
1¼" **right angle 80mm** superfinder	$209.50
1¼" **right angle** version, w/ star diagonal	$249.50
25mm cross-hair 1 ¼" eyepiece (12X)	$59.00
Large mounting rings for 80mm finder	$55.00
1¼" **star diagonal**	$49.00
Mounting brackets, 50mm finder	$39.50
1¼" **45°** diagonal /correct left-right views	$49.00
1¼" **90°** Amici diagonal, correct l/r views	$59.50

Celestron Telescopes

Celestar-8	$1099
Ultima 2000 8" (in stock)	$2699

Call for prices on all other model Celestron telescopes., including Schmidt-Cassegrains, Dobsonians and r

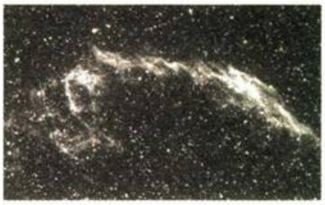
Enhanced Mirrors Boost Telescope Performance

1.32"	$39.50
1.83"	$49.50

90° star diagonals with 96% reflectivity enhanced aluminum mirrors in a CNC machined black anodized aluminum body. Performance far exceeds prism diagonals.

1 ¼" (1.32" mirror)	$99.50
2" (1.83" mirror) (see photo above)	$189.50

LUMICON FILTERS - BEST IN THE WORLD



AMAZING O-III FILTER™
"The LUMICON O-III proved to be our favorite . . .it gave the greatest contrast gain." *ASTRONOMY, February 1991*

Greatly Enhanced Detail
"Consistently performed well on all emission and planetary nebulae. Detail and structure were greatly enhanced in more than two dozen objects I viewed." *SKY & TELESCOPE, July 1995*

Better than a Dark Sky Site?
"From my light-polluted backyard, the view was better with my O-III than with any other filter tested. The view was even better than without the filter from a dark-sky site." *SKY & TELESCOPE, July 1995*

See The Horsehead!
"LUMICON's H-Beta Filter will show subtle features in emission nebulae that others fail to reveal. It can't be beat for the elusive Horsehead and California Nebulae." *SKY & TELESCOPE, July 1995*

Deep-Sky Filter™
BEST for Astrophotography!
"Stunning is all I can say," says noted astrophotographer Jack Newton. Great for both color and black and white photography.

Best Wide-Band Filter!
"Based on our tests, we'd recommend a LUMICON Deep-Sky and Oxygen III as complementary filters. The LUMICON Deep-Sky Filter clearly had the best contrast for reflection nebulae." *ASTRONOMY, February 1991*

LUMICON Multiple Filter Selector, holds 5 ¼" filters	$129; $99 if ordered w/filter
1¼" **LUMICON DEEP SKY Filter** threads into most 1¼" eyepieces	$99.50
48mm LUMICON DEEP-SKY Filter threads into most 2" eyepieces. Also fits EASY-GUIDERS	$199.50
2" LUMICON DEEP-SKY Filter threads into most 2" eyepieces. Also has male & female camera T-threads for prime focus photography	$199.50
72mm LUMICON Giant DEEP-SKY Filter (62, 67, 77mm adapter, $10, 82mm $16)	$399.50
2" Rear Cell Filter, fits SCT's............Deep-sky, $199.50 UHC,O-III, H-Beta	$199.50
1¼" **LUMICON UHC Filter** threads into most 1¼" eyepieces	$99.50
48mm LUMICON UHC filter fits most 2" eyepieces	$199.50
Choice of any two LUMICON filters (save 7%) .... 1¼" $185.00..............48mm	$370.00
LUMICON H-Beta Line Filter (9mm bandpass at 486nm) for the California Nebula, Horsehead Nebula ,and other extremely faint nebula. .... 1¼" $99.50 .... 48mm	$199.50
Oxygen-III Filter for very faint planetary and defuse nebula, 11nm bandpass at 496nm and 501nm O-III lines. ....1¼" $99.50 .... 48mm	$199.50
Lumicon Comet (Swan Band) FIlter..........1¼" $99.50 .... 48mm	$199.50
Universal Adapters for 1¼" filters. Adapts the filters to any 1¼" eyepiece	$19.50
Universal Adapter for 48mm or 2" filters. Allows use of any 1¼" eyepiece	$25.00

SKY VECTOR™ $299!!!

Includes Computer, Encoders, Hardware

NGC-Sky Vector
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MODE
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UP
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LUMICON

NGC-SKY VECTOR™ $439.00
12,000 objects! PC serial port NGC Sky Vector with IDENTIFY (Sky Tour) mode; 12,000 object memory including the corrected RNGC catalogue, IC catalogue, P&K planetary catalogue and much more.

LUMICON Sky Vector Features:

- "GUIDE" mode leads you to object
- Digital right ascension readout to 1 min.
- Digital declination reading to 10 arc/min.
- 4000 pulse (0.09 accuracy) encoders
- Polar Alignment NOT REQUIRED!
- Motor drive NOT REQUIRED!
- Just two stars to align
- Works Equally well for alt-azimuth telescopes like Coulter Odyssey and equatorial mounts like C-8, Meade 2080.
- No need to enter latitude, longitude etc.

SKY VECTOR I™ $299.00
NEW! With over 220 object memory including the 110 Messier and 58 best NGC objects.

SKY VECTOR II™ $349.00
Over 3600 objects! Also included planets and full visual descriptions.

Specify Telescope Type: Meade 4",8", 10",12" SCT, C-8, C-11, Odyssey 8", 10", 12", 17 ½" alt-azimuth; Meade 6"-16" Dobsonian. Ultima 8", 9 1/4", 11", add $25 C-14 add $75.

Deep Sky Astrophotography | PPF 400 NEW FILM

LUMICON Easy-Guiders™*

*US Pat. 4,448,500

Guide off-axis to make lovely astrophotos. All LUMICON Easy-Guider™ off axis guiders have both radial and 360° rotational adjustments for 5x easier guide-star selection, use 48mm filters, 360° camera rotation, large prisms for bright guide stars. Specify camera and telescope type.

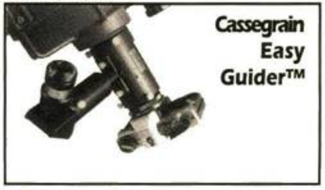
NEWTONIAN Easy-Guiders

NEWTONIAN Easy-Guider	$189,50
48mm coma corrector/field flattener	$285.00
1.8X multiplier (2" Deluxe Barlow)	$259.00
3x relay diagonal	$99.50
Illuminated recticle eyepiece, pulsed	$119.50
Guider for Hasselblad	$489.00
Guider for Mamiya 645	$259.00

CASSEGRAIN Easy-Guiders
for C-8, Meade 2080, Cynamax 8, includes 50mm achromatic lens for f/6 operation (3x shorter exposures!). Superb rich field viewing too.

Cassegrain Easy-Guider	$249.00
Adapter for Hasselblad	$299.00

Mamiya 645 $119; Pentax 6x7 add $129, Pentax 645 add $149.



GIANT Easy-Guider
For Celestron 11, C-14 and the 10"-12" Meades. Includes 80 mm clear aperture achromatic lens for edge-to-edge illumination & pinpoint star images. f/ratio adjustable f/4 to f/11. Also yields unmatched rich-field viewing.

Giant Easy-Guider	$395.00

Adapter for Hasselblad $399; Mamiya 645 $149; Pentax 6x7add$139; Pentax 645 add $159.

48mm Deep-Sky Filter ordered with any Easy-Guider, (save $20)	$179.50
Illuminated recticle eyepiece	$119.50
Cable Release	$9.95
Declination motor (state scope type)	$109.00

Film Hypersensitization Kits*
LUMICON Hyper-Kits™ yield 3-15x film speed gain in long exposures. They are safe and simple to use. Easy Hyper-Kit™ includes a chamber with all controls and fittings, thermometer, a refillable cylinder of non-flamable forming gas and a hand operated vacuum pump. **US Pat. 4,473,636*

Model 300 Hyper-Kit sensitizes any 35mm film in hours. Best for 2415. Achieves highest possible film speeds	$325
Model 600 Hyper-Kit Like the Model 300, but also sensitizes 120/220 larger film and small glass plates.	$395
Model 1200 Hyper-Kit is for 4x5" plates and film up to 5x7" . Has 2 gas cylinders & temperature controller.	$595
Temperature controller for any kit	$75
Electric Vacuum Pump, Model R-10	$325

Try PPF Hypersensitized Film
LUMICON Hypersensitized film: essential for good deep-sky astrophotography. (Deduct 10% for 3 or more rolls.)

Kodak PPF-400 THE BEST!, 36exp.	$14.95
2415 Ultrafine B&W, red sensitive, 36 exp.	$13.95
Fuji G800 Fine Grain color neg. 24 exp.	$13.95
Ektachrome1600, fast slide film, 24 exp.	$19.95
Fujichrome RD 1000, fine grain slide, 24 exp.	$12.95
D-19 B&W Developer, 1 gal.	$8.50
Portra 400, 120 size VC or NC	$19.95

Meade & Celestron

Lumicon carries a full line of
Meade & Celestron Telescopes & Accessories
All at competitive prices & with FAST delivery
California residents add 8.25% sales tax

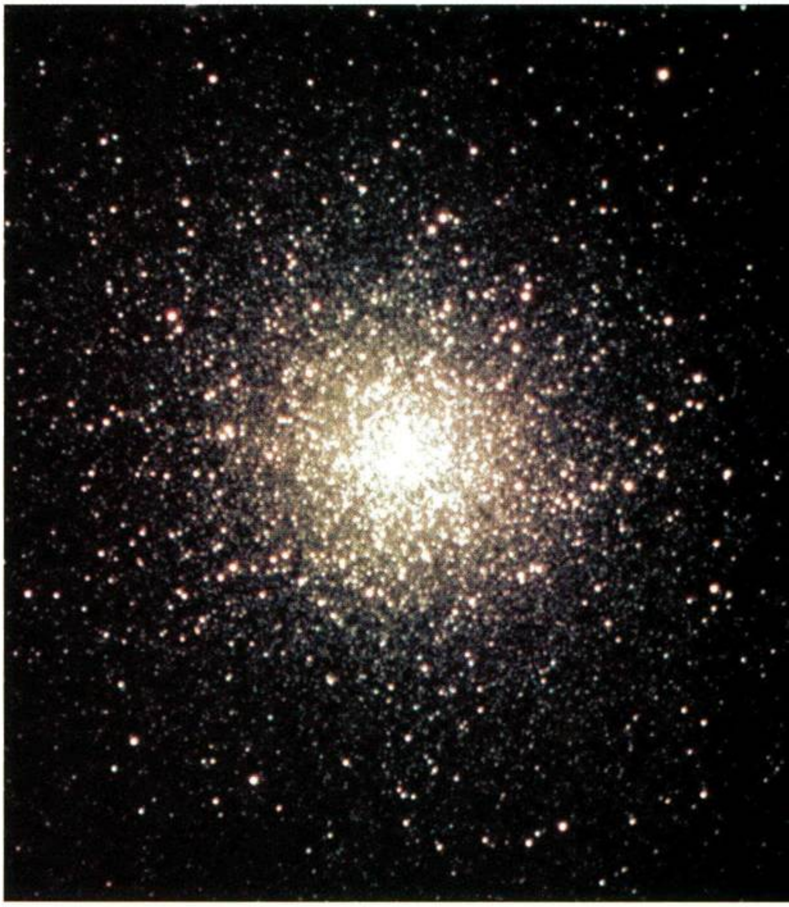
Razor-sharp optics and precision techniques capture stunning portraits of galaxies, clusters, and nebulae in vibrant hues.

Photographs by Tony and Daphne Hallas.

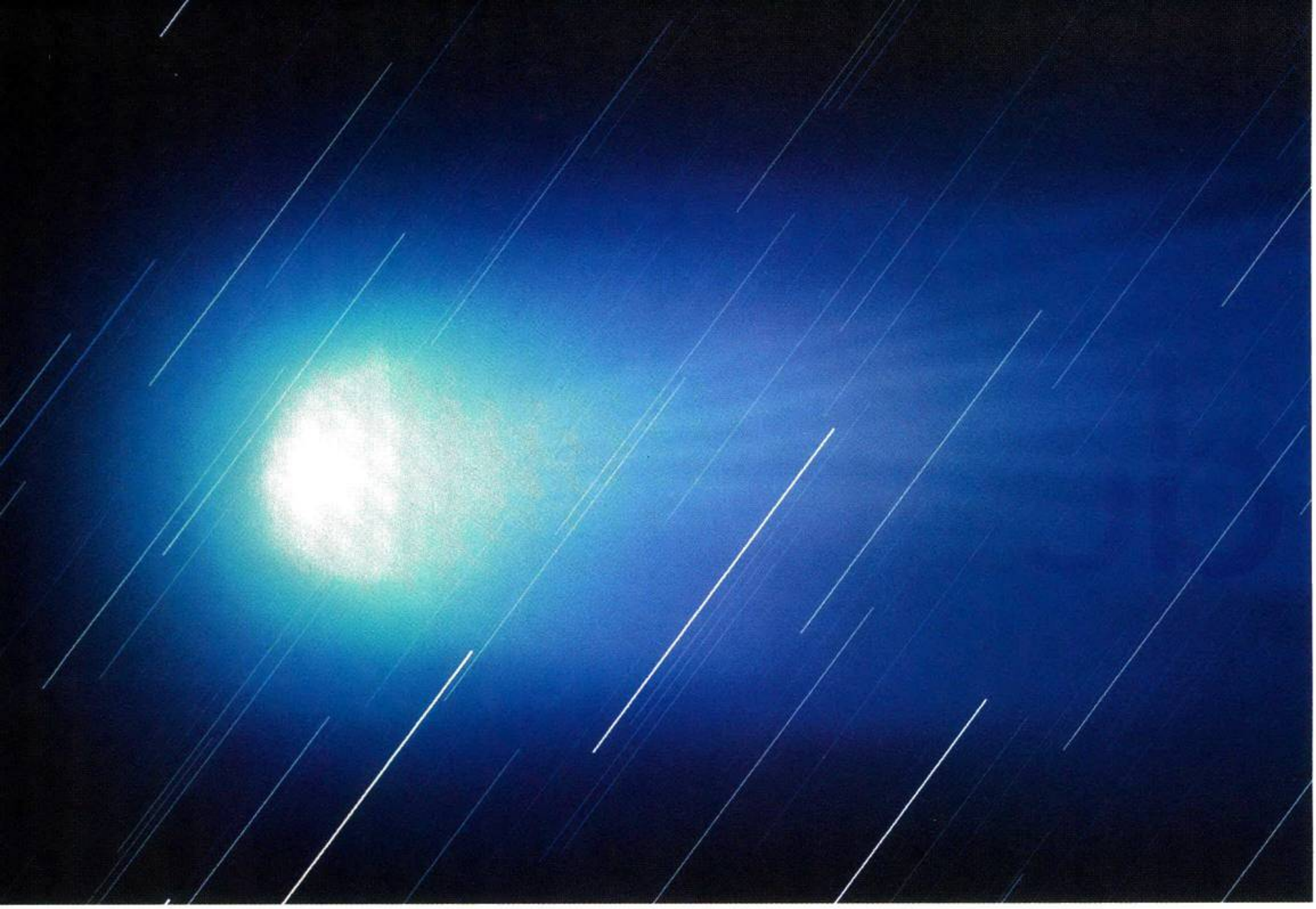
the universe in

deep color

You may think these images are the newest releases from the Keck telescopes, but you'd be wrong. Amateur astrophotography has soared to new heights in recent years. Californians Tony and Daphne Hallas shot these astronomical wonders from the dark skies of Mt. Pinos. A rainbow palette is revealed in the spine of a galaxy, the smokey breezes of nebulae, and the furnaces of stars. Consider these vibrantly colorful pictures our holiday gift to you.



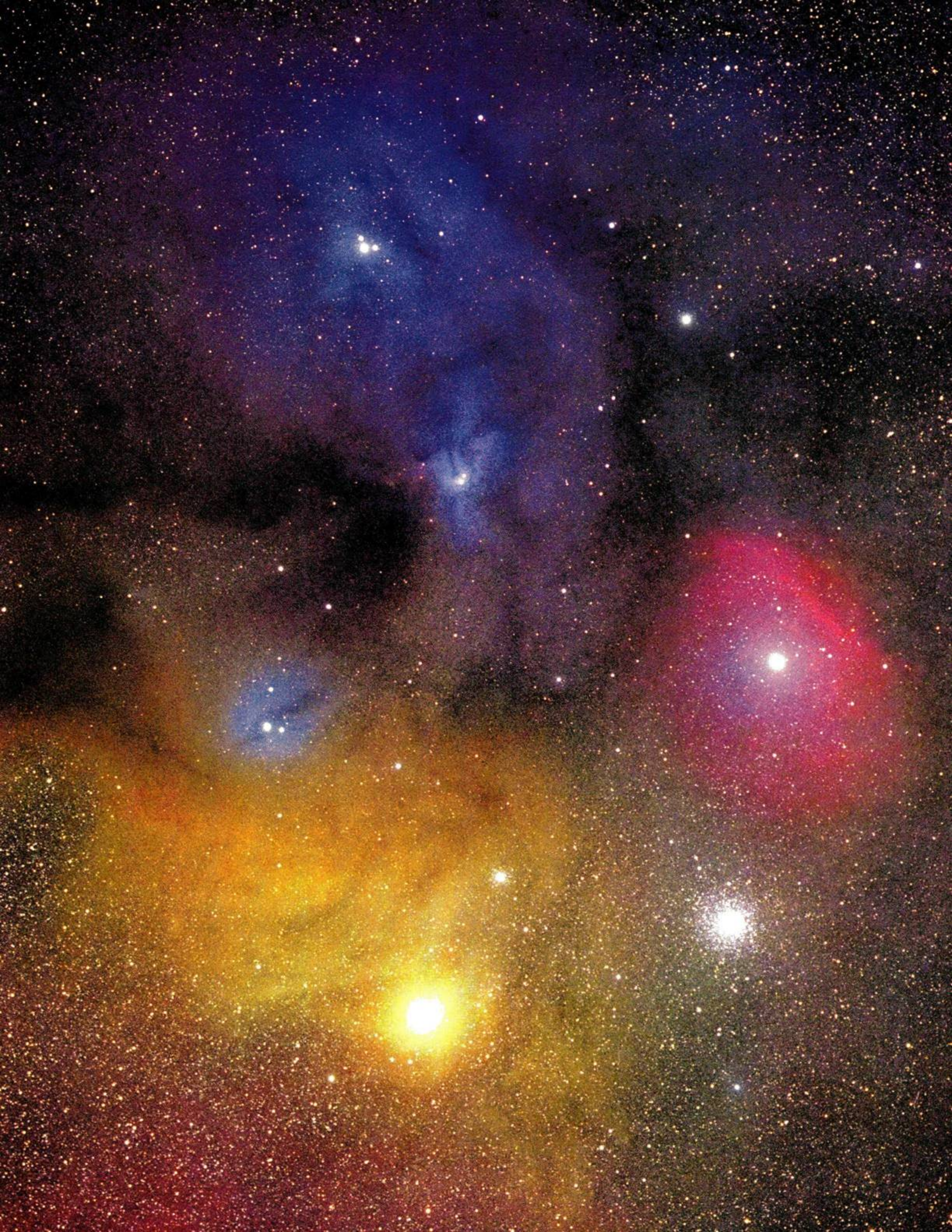
Left: The Omega Nebula, M17 (12.5-inch f/7 reflector, hypered PPF film, composite of two 45-minute exposures)
Above: The Hercules Cluster, M13 (14.5-inch f/8 Cassegrain, hypered HQ 100 film, 90-minute exposure)

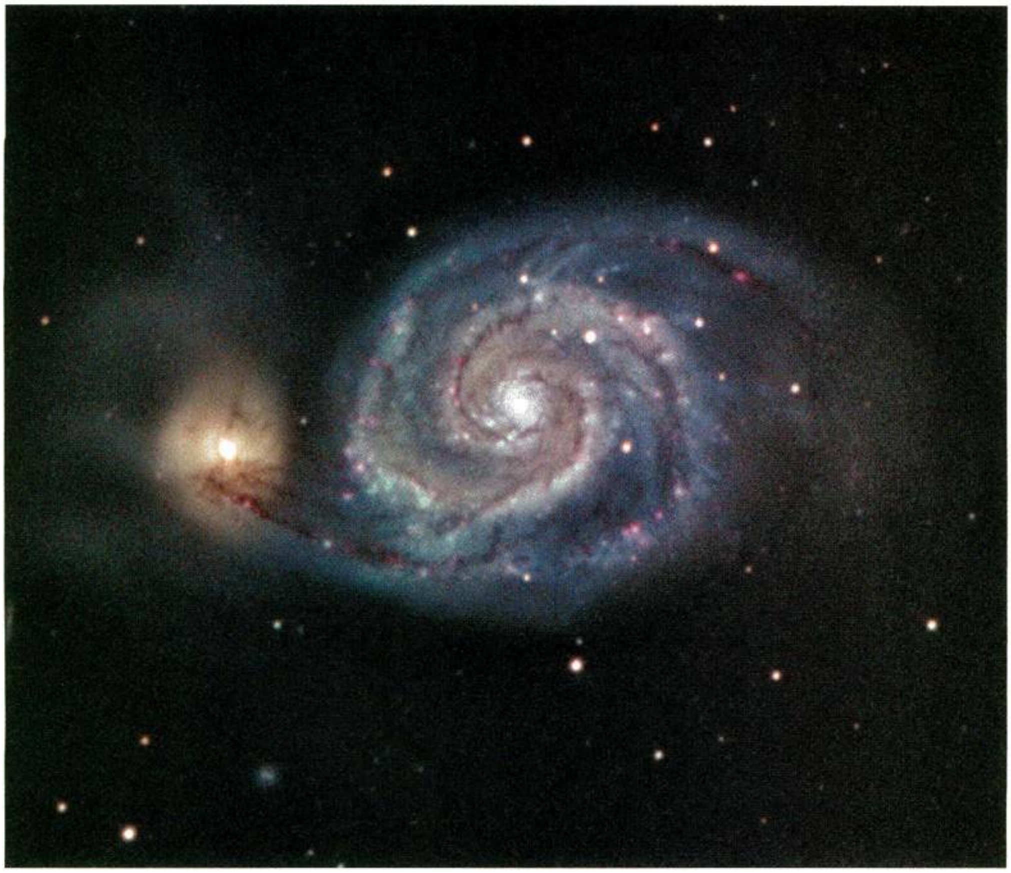


Above: Comet Hyakutake (7-inch f/7 apochromatic refractor, 120 format hypered PPF film, tracked on the nucleus)

Right: The Bubble Nebula, NGC 7635 (14.5-inch f/8 Cassegrain, hypered HQ 100 film, 90-minute exposure)

Opposite page: The Rho Ophiuchi Region, including Antares and globular star cluster M4 (4-inch f/6 refractor, 120 format hypered PPF film,90-minute exposure)

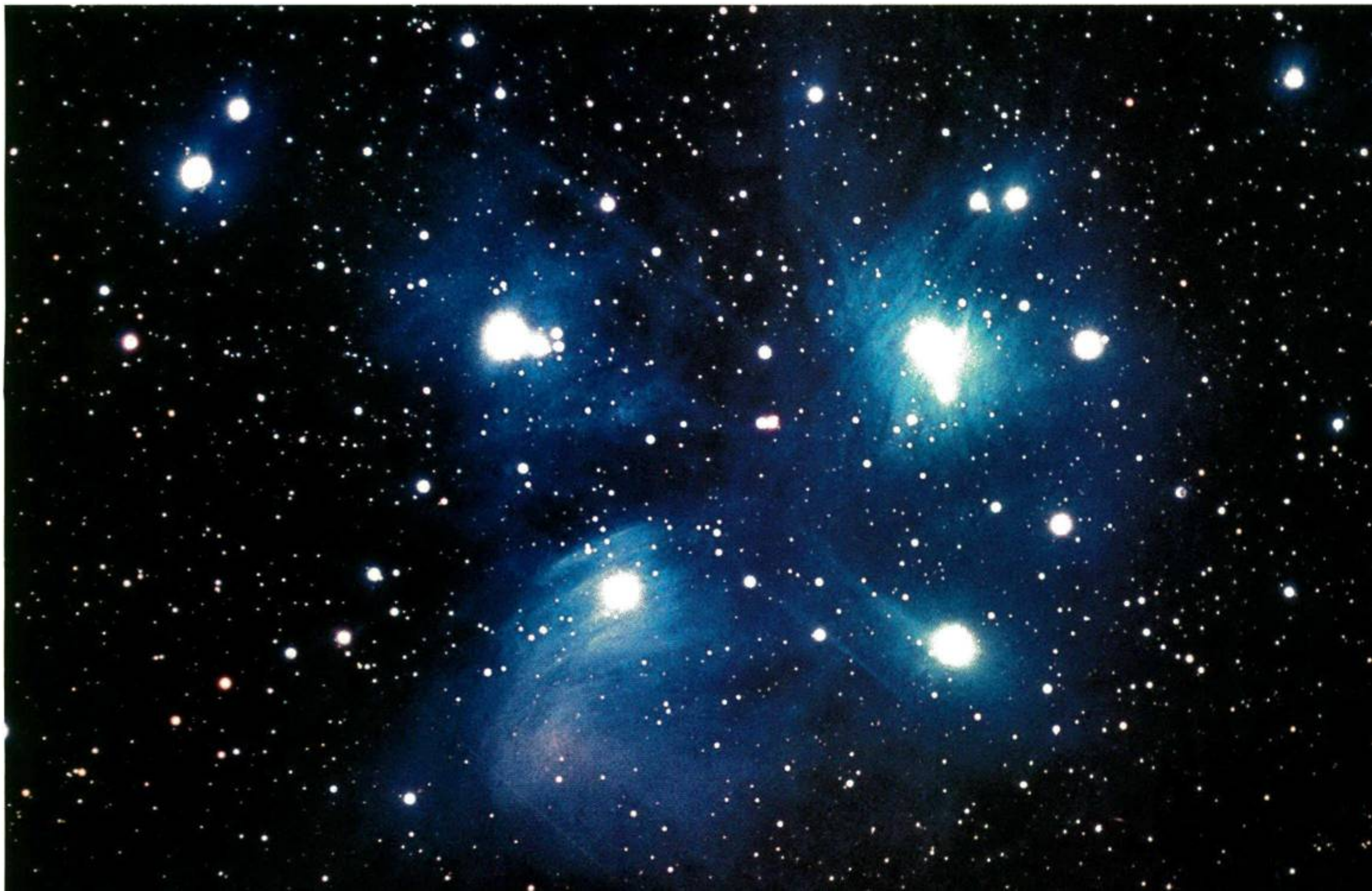




Opposite page: The Trifid Nebula, M20 (14.5-inch f/8 Cassegrain, hypered PPF film, composite of two 45-minute exposures)

Left: The Whirlpool Galaxy, M51 (14.5-inch f/8 Cassegrain, hypered PPF film, composite of three 60-minute exposures)

Below: The Pleiades, M45 (7-inch f/7 apochromatic refractor, 120 format hypered Super HG 400 film)



STAR STUFF

PRODUCTS

From January through December, the following calendars will take you through 2000 in style. Each features beautiful images and several hold astronomical events (both current sky and historical) and observing tips.

Astronomy Magazine 2000 Calendar

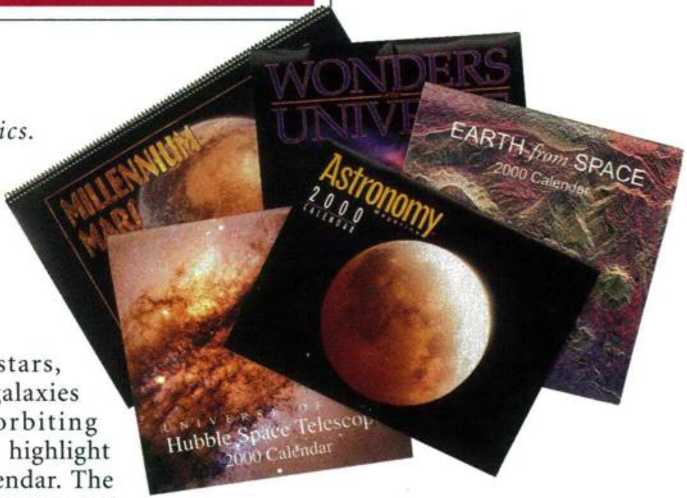
▶ This 13½" by 21" calendar captures the most dramatic celestial events of the year. Stunning photographs and artwork include images of a total lunar eclipse, a pair of galaxies colliding, and a Hubble Space Telescope image of Saturn. Each month also holds information on viewing the planets and other celestial events.

Kalmbach Publishing, 21027 Crossroads Circle, P.O. Box 1612, Waukesha, WI 53187-1612; phone, (800) 533-6644; email, customerservice@kalmbach.com; website, http://www.astronomy.com. *Astronomy* Magazine 2000 Calendar: *$12.95 (plus shipping and handling).*

Earth from Space 2000 Calendar

▶ The 12" by 24" wall calendar holds images of mountain ranges, volcanoes, rivers, and oceans obtained with NASA's SIR-C/X-SAR spaceborne imaging radar, which is flown on the Space Shuttle as part of NASA's "Mission to Planet Earth." The images are rich in vibrant color and dramatic texture. They reveal the stark beauty of our planet from a very different perspective.

Astro-Graphics, 85 Oakside Drive, Smithtown, NY 11787; phone, (888) 827-8768; fax, (516) 366-5356; website, http://www.astrographics.com. Earth from Space: *$12.95 (plus shipping and handling).*



MILLENNIUM MARS
WONDERS UNIVE
Astronomy 2000 CALENDAR
EARTH from SPACE 2000 Calendar
UNIVERSE OF Hubble Space Telescope 2000 Calendar

Universe of the Hubble Space Telescope 2000 Calendar

▶ Images of planets, stars, gaseous nebulae, and galaxies captured by NASA's orbiting Hubble Space Telescope highlight this 12" by 24" wall calendar. The images have been digitally processed to reveal the elegant and subtle beauty of the most distant realms of the universe. Includes accurate and informative descriptions by a professional astronomer. Printed in brilliant color on premium stock.

Astro-Graphics, 85 Oakside Drive, Smithtown, NY 11787; phone, (888) 827-8768; fax, (516) 366-5356; website, http://www.astrographics.com. Universe of the Hubble Space Telescope: *$12.95 (plus shipping and handling).*

Wonders of the Universe 2000 Calendar

▶ Enjoy the endless beauty of the universe represented by 12 spectacular full-color photographs from independent photographers, observatories, and space agencies. This calendar, the 19th edition of the *Wonders of the Universe*, provides month-by-month details of planetary movements; lunar phases; lunar occultations; space-science anniversaries; and US, Canadian, and British holidays all in a large 12" by 24" format. Printed on 100-pound book stock recycled paper.

Hansen Planetarium Publications, 1845 South 300 West #A, Salt Lake City, UT 84115; phone, (801) 483-5400; orders, (800) 321-2369; fax, (801) 483-5484; website, http://www.utah.edu/Planetarium/Publications.html. Wonders of the Universe: *$12.95 (plus shipping and handling).*

Millennium Mars 2000 Calendar

▶ This limited edition (only 2,500 were printed), large format (11" by 17") calendar is actually two calendars in one. The first is an Earth calendar beginning December 20, 1999, and continuing through February 1, 2002. Overlapping Earth's monthly cycle is a 20-month Mars calendar. Each of the 54 pages are stuffed with full-color original illustrations that are highlighted by stunning panoramas for each martian month. Also included are essays on martian planetary science and terraforming.

Institute of Implied Science, P.O. Box 45926, Madison, WI 53744; website, http://www.tomorrowsf.com/market/mars/welcome.html. Millennium Mars: *$35 (plus shipping and handling).*

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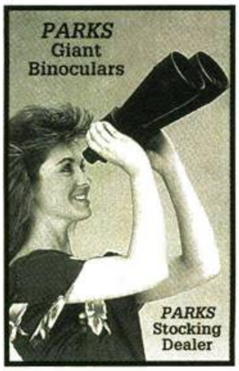

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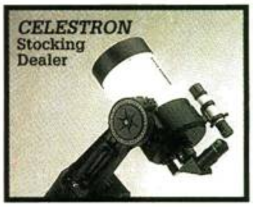

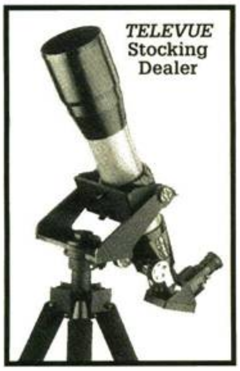

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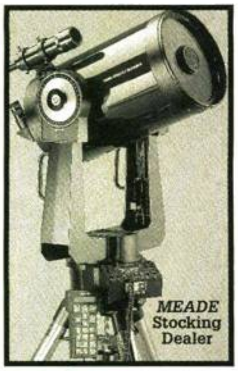

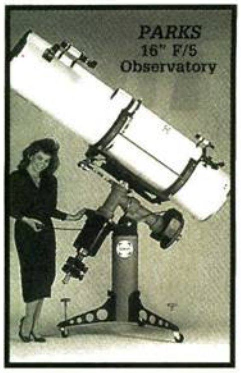

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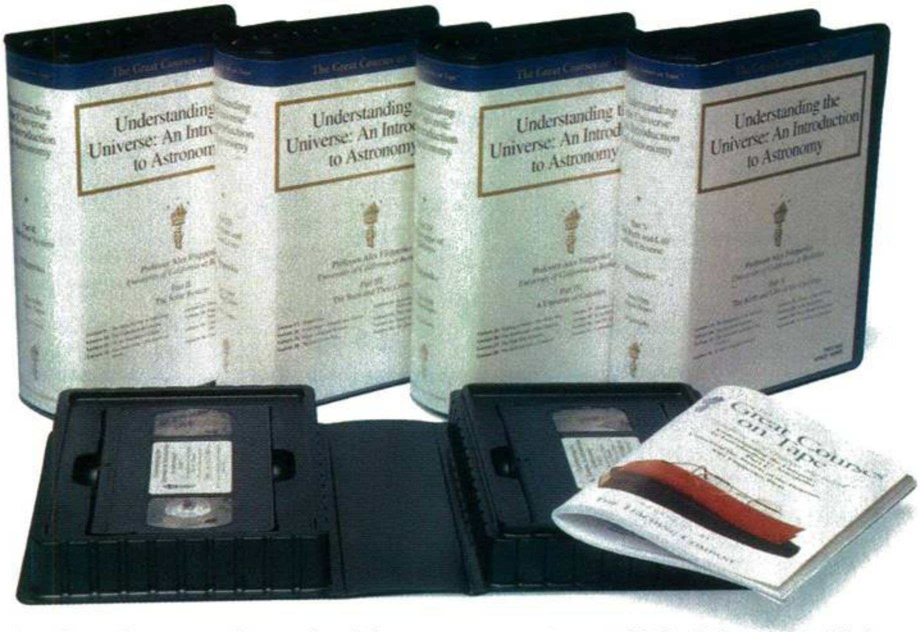
The Teaching Company, 7405 Alban Station Court, Suite A-107, Springfield, VA 22150-2318; phone, (800) 832-2412; website, http://www.teachco.com. Understanding the Universe *(10 videotapes and accompanying course guides): $499.95 ($20 shipping and handling).*


Understanding the Universe: An Introduction to Astronomy
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Life Beyond Earth

▶ How much life is out there and how could we find it? These are the central questions addressed in the two-hour documentary *Life Beyond Earth*, airing Wednesday, November 10 on public television. This is the first television program in 14 years from acclaimed science writer and *Astronomy* editorial advisory board member Timothy Ferris, who wrote and narrated the text.

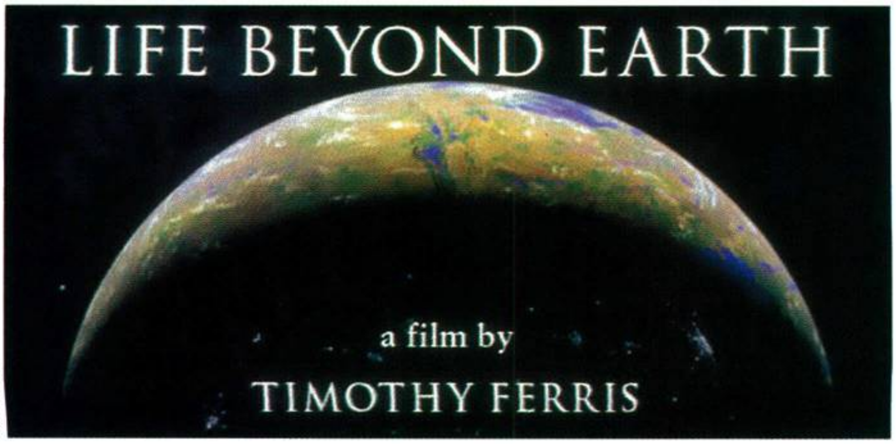
The first hour, titled "Are We Alone?" explores the origin and evolution of life. As Ferris explains early on, the three key ingredients for life — energy, water, and organic molecules — are ubiquitous through the cosmos. And with 400 billion stars in our galaxy alone, there are plenty of places for life to get started. Ferris describes recent discoveries to build a convincing case that life must be common throughout the cosmos.

Just as he did in his 1985 classic, *The Creation of the Universe*, Ferris employs visuals that are more than mere eye candy. To help the viewer grasp the immensity of time, he uses a 5-kilometer stretch of highway in the Utah desert to symbolize the 4.6-billion-year history of Earth. On that scale, "the whole human story lies in this last half meter, easily overlooked on a 5-kilometer highway through time," says Ferris. "All recorded history . . . lies in this last few millimeters."

Having established that life is likely to be commonplace, Ferris moves on to the question of intelligence. In the second hour, "Is Anybody Listening?" Ferris explores the likelihood of primitive life evolving to high intelligence and how long civilizations might last. He uses flickering Christmas tree lights to demonstrate the vital importance of lifetime. If communicative civilizations nuke themselves into oblivion or choke to death in their own pollution, the lights blink on and off so quickly that no two civilizations populate the Galaxy at the same time. Only if some civilizations endure for vast stretches of cosmic time will the Galaxy be brimming with intelligent life. "SETI requires that alien radio buffs stay on the air a lot longer than we have. The great void in interstellar communication is not space, but time," says Ferris.

Ferris concludes the video by asking "What would you say to them?" Ferris provides his own eloquent answer, but more importantly, viewers are left to ponder the question themselves.

With the exception of a few minor gaffes (a graphic shows Magellan's ships sailing around the world the wrong way, volcanoes and plate motions aren't powered by molten cores), this is a powerful film. With an elegance and economy of language, Ferris manages to cover a sweeping range of science in two hours while probing some of the deepest questions humans have ever asked. — *Robert Naeye*



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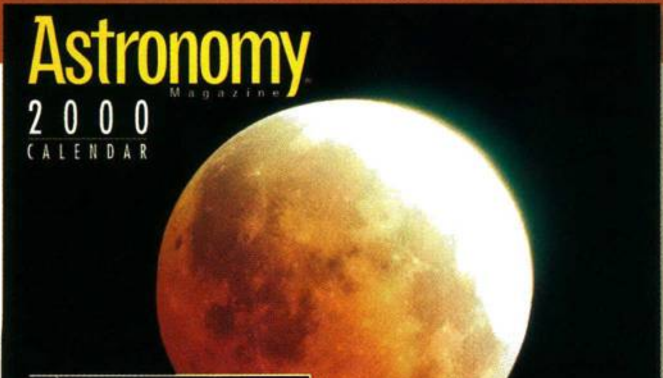

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BOOKS

The Invisible Universe

David Malin, 133 pages, Bulfinch/ Callaway Press, Boston, 1999; ISBN 0-8212-2628-2; hardcover, $50 until 12/21/99, $60 thereafter.

The Universe and Beyond, Third Edition

Terence Dickinson, 168 pages, Firefly Books Ltd., Buffalo, N.Y., 1999; ISBN 1-55209-377-8; (hardcover), $40; ISBN 1-55209-361-1; (paperback), $29.95.

A Photographic Tour of the Universe, Revised Edition

Gabriele Vanin, 143 pages, Firefly Books Ltd., Buffalo, N.Y., 1999; ISBN 1-55209-345-X; paperback, $24.95.

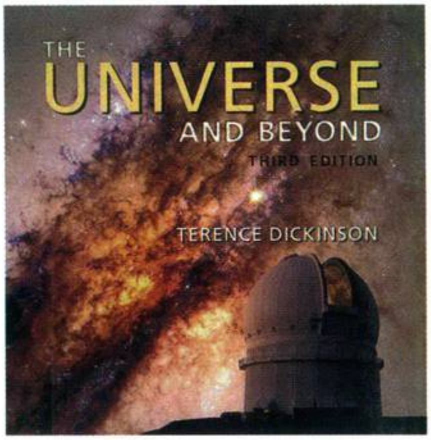
Magnificent Universe

Ken Croswell, 224 pages, Simon & Schuster, New York, 1999; ISBN 0-684-84594-6; hardcover, $60.

Other Worlds: The Solar System and Beyond

James Trefil, 240 pages, National Geographic Books, Washington, 1999; ISBN 0-7922-7491-1; hardcover, $35.

▶ A number of recently published books highlight the beauty and complexity of the cosmos. Each has its own unique theme and design. You are sure to find a book that satisfies the most avid astronomer on your holiday gift list.

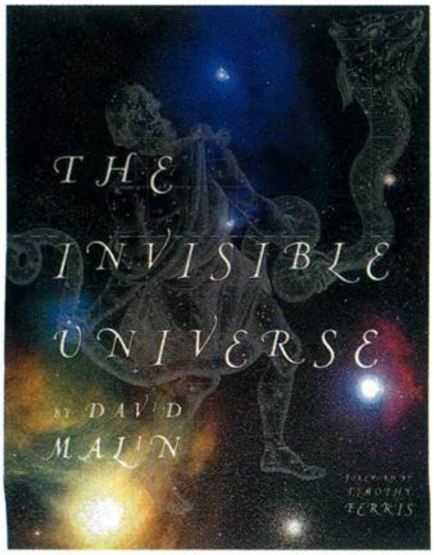


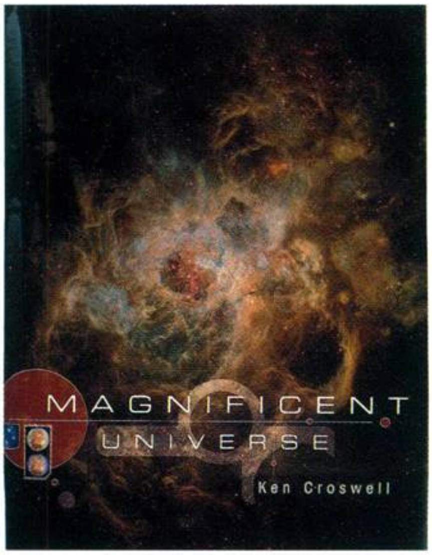
Veteran Canadian astronomer Terence Dickinson has updated his classic *The Universe and Beyond*. Dickinson's book is comprehensive and thoroughly covers the solar system, stars, the Milky Way, and other galaxies. The "beyond" subjects include cosmology, dark matter, extraterrestrial life, UFOs, and the ultimate fate of the universe. We are even given a glimpse of the next century's telescopes and how they may help astronomers answer some age-old questions. The book is lavishly illustrated with astrophotos, artwork, and diagrams.

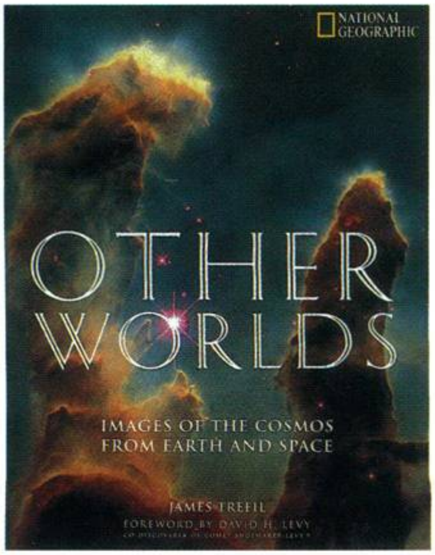
Italian astrophysicist Gabrielle Vanin has also revised his book, *A Photographic Tour of the Universe*. Vanin begins with the history of astronomical imaging, including telescopes, photography, CCDs, and satellite observatories. The cosmic tour begins with the solar system and journeys out to the stars and far beyond. Figure captions form the basis of the text and Vanin uses illustrations to explain concepts and terminology as needed. The new edition includes a chapter detailing some of the spectacular results from the Hubble Space Telescope.

Renowned British astrophotographer David Malin weaves his usual magic in *The Invisible Universe*. Malin obtained all his stunning images using ground-based telescopes and his unique image-enhancing techniques. He shows us many familiar objects, and the large format of the book allows us to appreciate them in a new way. Each image has its own story. The book weaves a charming mix of history, mythology, poetry, and astronomical fact along with Malin's personal voyage of discovery. The only down side is the lack of new images; most were previously published in Malin's 1993 book, *A View of the Universe*.

In *Magnificent Universe*, astronomy writer Ken Croswell reveals the beautiful and exotic. He details the denizens of our solar system including the often-neglected Earth and her moon. Croswell also explores the members of our Galaxy, including stars, stellar remnants, and the interstellar medium. He then journeys to the realm outside the Milky Way by examining galaxy shapes, clustering, and collisions.







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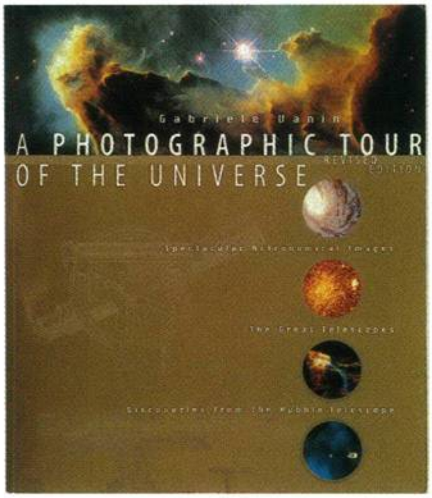
Gabriele Vanin
A PHOTOGRAPHIC TOUR OF THE UNIVERSE
REVISED EDITION
Spectacular Astronomical Images
The Great Telescopes
Discoveries from the Hubble Telescope

The final chapter discusses our current understanding of the origin and evolution of the universe. Croswell's narrative is crisp, concise, and entertainingly informative.

Physicist and *Astronomy* editorial advisory board member James Trefil explores the origin and evolution of our solar system and the universe in *Other Worlds: The Solar System and Beyond*. Trefil begins with a discussion of cosmic scales. He then takes us on a comprehensive tour of the solar system by describing the historical development of astronomical knowledge and the discoveries that revolutionized the field. The final chapter briefly examines the Milky Way Galaxy and the universe beyond. Trefil's style is authoritative yet conversational and the book is a visual treat.

Each of these books has its share of breathtaking images, but the most visually stunning are those by Croswell, Malin, and Trefil. These books devote an entire page to each image. In terms of content and style, there is considerable variation. Dickinson's narrative is lively and eloquent, while Malin is more philosophical than the others. However, Malin's book does not include the solar system.

Both Croswell and Trefil have succeeded in writing books that are fun, fact-filled, and concise, making them suitable for a wide audience. They also hold a lot of material on the planets, which may make them more appealing to children.

Vanin's book is packed with pictures and text is sparse, making it a good choice for those who simply desire to marvel at the splendor of nature without feeling compelled to do a lot of reading. Any of these books would make a fine holiday gift for the astronomical enthusiast on your list, just remember to include your own name. — *Jennifer Birriel, University of Pittsburgh*

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The Star of Bethlehem: The Legacy of the Magi

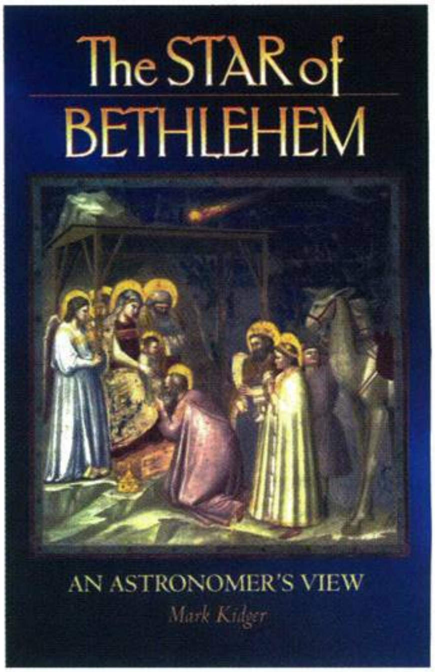
Michael R. Molnar, 208 pages, Rutgers University Press, Rutgers, N.J., 1999; ISBN 0-8135-2701-5; hardcover, $25.

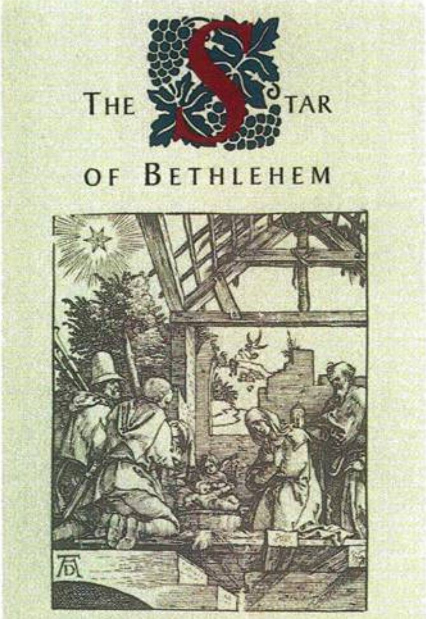
The Star of Bethlehem: An Astronomer's View

Mark Kidger, 300 pages, Princeton University Press, Princeton, N.J. 1999; ISBN 0-691-05823-7; hardcover, $22.95.

▶ For two millennia, scientists have searched the heavens for an astronomical explanation for the Star of Bethlehem. Now two of these scientists, astronomers Michael Molnar and Mark Kidger, impart their research on what this legendary object might have been.

Kidger, a researcher at the Instituto de Astrofisica de Canarias, in Tenerife, Spain, compares Matthew's tale to lesser known accounts that were excluded from the Bible. He places Christ's birth between 7 and 5 B.C. then systematically leads the reader through arguments for and against astronomical candidates such as Venus, a planetary conjunction, meteors, a nova, and others.





Molnar, an astronomer and former manager of Physics Instructional Labs at Rutgers University, believes the star was a "regal portent centering around the planet Jupiter that was eclipsed by the moon" on April 17, 6 B.C. With an easy and eloquent style, Molnar leads readers through this intriguing detective story. He uses a combination of astronomical, astrological, and historical clues to lead readers to his scientific conclusion. ■

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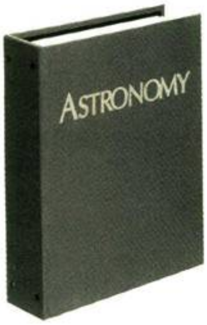

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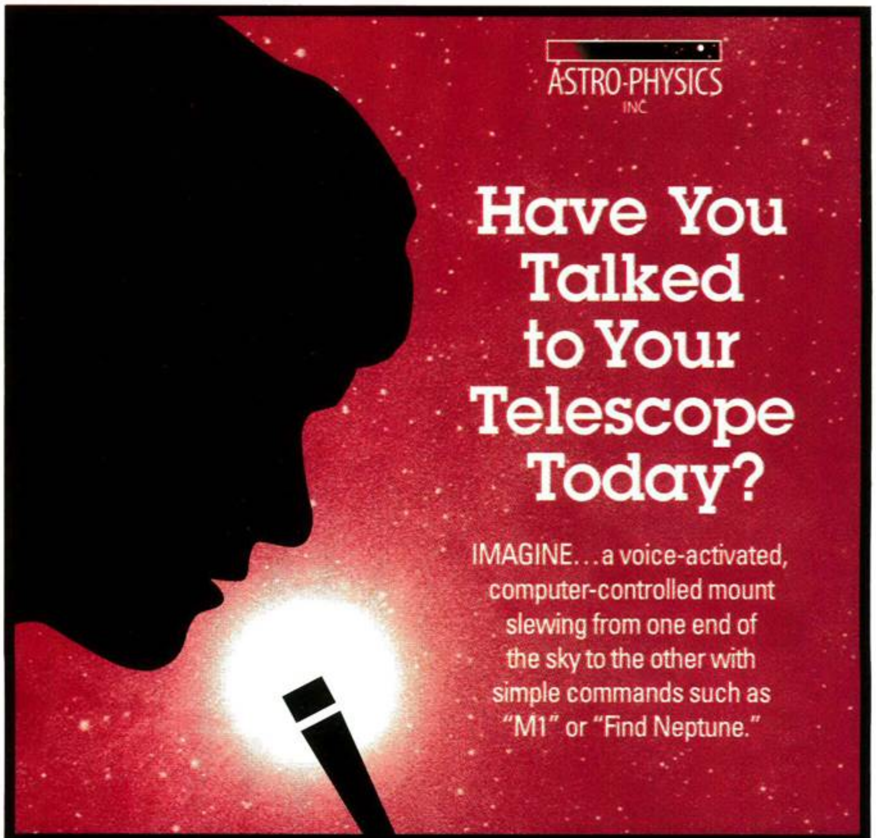

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Hardly a day goes by that we don't get a note or E-mail message like the one reprinted on the next page, or a call that goes something like this: "Your ads are right. So and so on the East Coast advertises low prices – but they don't have what I want in stock, they couldn't answer *any* of my questions, and they wanted my credit card number before they'd even *talk* to me. They said if I wanted to ask questions, I should call the manufacturer . . . and then they hung up on me!" One of our customers added, "If I wanted that kind of abuse, I would have called my ex-wife."

If you want the right telescope, you need more than a camera store clerk with a price list, a surly attitude, and a wild guess.

What you *really* need are people who will take the time to listen to what *you* need, people with years of experience using and selling telescopes, people who can help you get the most telescope for your dollar. That's exactly the kind of people you'll find at ***astronomics***.

Unlike camera stores and shopping mall gift shops, telescopes are our specialty at ***astronomics***, not just a sideline. We're a family-owned full-line telescope dealer – not just a few toy telescopes stuck off in the corner of some no-help department store, toy store, or gift shop as an afterthought. We don't work on commission, so we won't try to sell you more than you need just to pad our paychecks.

We've been helping people choose the right telescope since 1979. We have the experience to help *you* pick the scope that fits your needs . . . *and your budget* . . . from the many Meade, Celestron, TeleVue, Takahashi, and Questar telescopes we stock at discount prices from $119 to $27,995. (We had over 750 telescopes *in stock* as we wrote this.)

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We order Meade telescopes and accessories by the ton . . . literally!

Meade 203SC **$895**

The day before this copy was written, we received 305 cartons from Meade – *3¼ tons* of scopes and accessories in one shipment. We don't know of many other dealers – if any – who regularly receive, or actually stock, Meade products in those quantities . . . *no matter what they claim.* But we do. Meade telescopes, binoculars, eyepieces, filters, Magellan computers, Barlows, off-axis guiders, illuminated reticle eyepieces, counterweights, T-adapters, tele-extenders – we keep them all in stock.

It doesn't matter whether the right telescope for you is one of the computerized 8" or 10" **LX200 Schmidt-Cassegrains**; the **LX200 Maksutov-Cassegrain** 7" to the right; or any of the 8" or 10" **LX50** SCTs. It doesn't matter if it's the 3.5" **ETX-90EC** or 5" **ETX-125EC** Maksutovs with optional go-to computer shown at the top of this page (we had 24 of the 90mm in stock and 600 of the 125mm on order as this was written). It doesn't matter if it's the **203SC/500** German mount 8" SCT, shown above left at its new lower price. If Meade is shipping it for a dealer to keep in stock, the chances are good that we *have* it in stock.

Meade prices are about the same anywhere you call. So why order a Meade telescope or accessory from a dealer who charges your credit card, then makes you wait and wait until he finally gets around to ordering what you want? Not when you can usually get the Meade you want . . . right now . . . at the right price . . . right here at ***astronomics.***

Meade 7" LX200 **$3295**

We buy Celestron by the ton, too!

The week this was written, we received 9791 pounds of Celestron scopes and accessories in a single shipment – 21 pallets, a full trailer load. The week before, we got a separate 3950 pound shipment from Celestron. We have *402* Celestron scopes in stock for immediate shipment, plus accessories galore. We don't know of many other dealers – if any – who order and stock Celestron in those quantities. But we do.

Because we buy in large quantities, we can take advantage of special buys. And we pass those extra savings on to you.

We stock Pentax eyepieces.

From 5.2mm to 40mm, we stock all the Pentax wide field (55°-65°) long eye relief (20mm) ultra-premium ED glass eyepieces . . . all at *very* unpremium prices.

We have Celestron's new NexStar 5 go-to computerized scope!

Celestron 5" NexStar 5
$1199

The Celestron 5" NexStar 5 computerized scope puts sharp and bright f/10 Schmidt-Cassegrain optics into a sleek metal housing that takes go-to telescopes into the next millennium in style!

The NexStar's *standard equipment* computer hand control stores snugly in a recess in the rigid single metal fork arm (and can be operated while stored there, as well as when it's undocked and hand-held at the end of its coiled cord). The computer quietly moves the AA-battery powered NexStar to 18,473 stars and objects at a fast 6.5° per second. It also takes you on guided tours of the most spectacular deep sky objects that are visible on the night you are observing. An AC adapter is standard, not an option. Also standard are electric slow motion controls; a 26mm Plössl eyepiece with a field of view that's more than twice as wide as the full Moon; and a non-magnifying Star Pointer red dot finder that's ideal for eyeglass wearers.

NexStar hand control

Celestron's 5" true-multicoated optics have been used on the Space Shuttle. If they're good enough for NASA, imagine what they can show you. Then imagine what the NexStar 5 can *find* for you – *automatically!*

We have more than 50 Celestron 8" Dobsonians in stock!

Celestron 8" Star Hopper
$429

If you're looking for a Dobsonian reflector this holiday season, look no further. We have them in stock. The **8" f/6 Celestron Star Hopper**, left, has a unique dovetail balance that doesn't need springs or beanbags to keep it stable under heavy loads. Its low thermal mass Pyrex mirror cools down to operating temperature faster than a conventional slab mirror, plus its high light transmission five-step enhanced aluminum mirrors mean brighter images than conventional coatings. You'll not only see sooner, you'll see more. And you'll see it all for less money at our new lower price.

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We'll sell you the *right* telescope.

The right scope might be a TeleVue.

TeleVue TV-85, in stock, **$1995**

Hardly a week goes by that TeleVue doesn't send us a copy of a new warranty card from one of our customers – to let us read the glowing comments about the TeleVue scope they bought from us. While we're pleased to hear we've satisfied another customer, we've come to expect nothing but praise for TeleVue scopes.

TeleVue's short focal length ultra-premium refractors give you an observing flexibility many other scopes lack. Each has the ability to go from very low power wide angle views (as low as 9x in some cases, with a wide 5.7° field) to very high power observing (one test report said they used an amazing 89x per inch of aperture on the Ranger, the least expensive TeleVue), all without losing optical quality.

Pronto, **Ranger**, the **TV-85** and **TV-101**, the brass **Renaissance** – all TeleVue refractors are built to the same uncompromisingly high optical and mechanical standards. At the time this was written (8/10), we had every TeleVue scope in stock at ***astronomics***.

All TeleVue eyepieces are in stock

We also stock TeleVue eyepieces, Barlows, and accessories in depth. Whether it's a Plössl, Nagler, Nagler 4, Radian, Panoptic, Paracorr, Powermate, Tele-Pod, Gibraltar, Qwik-Point, Starbeam, or BinoVue – we carry them all. If it's a TeleVue, chances are very good we have it in stock.

The right scope might be a Questar.

Questar 3.5" Standard **$3399**

For many people, the thought of a 3.5" scope that *starts* at $3399 is enough to curl their toes. But for those who want the best small telescope made, $3399 is a bargain.

Solar filters for eyepiece and finder, built-in Barlow, two ultra-premium eyepieces, a velvet-lined hard case, a star chart on the slide-on lens shade with a Moon map beneath – all are standard on a Questar . . . and unavailable from the competition.

Want a Questar, the premier portable telescope? We stock them.

It might be this 4.5" Bushnell for only $199!

BUSHNELL

Bushnell Voyager 4 **$199**

For most people, Bushnell means binoculars and small "department store special" telescopes. But Bushnell is getting into serious entry-level astronomical observing with their new and reasonably-priced imported tabletop and Dobsonian reflectors.

The **4.5" f/4.4 Voyager**, right, has two 1.25" eyepieces (16x and 100x), a true rack and pinion focuser instead of rubber roller focusing, a carrying strap, a tripod-adaptable altazimuth tabletop cradle mount, and a price that's much, much lower than similar-design factory-direct competitve scopes.

If you want a full-sized Dobsonian scope, a 6" f/8 Bushnell *metal-tube* Dob costs $299 and an 8" f/6 is only $399! Both come with a 6 x 30mm finder and 25mm eyepiece (49x) as standard equipment.

One small step for man. One quantum leap for binocular observing.

"Truly a quantum leap in binocular observing." That's how *Sky & Telescope* reviewed the image-stabilized **Canon 15 x 45mm** binoculars. They also said "astounding . . . supercrisp . . . particularly impressive was how well these binoculars compared to much larger apertures . . . totally blew away what I had seen in the 7 x 50s!" For handheld, rock-solid, wide field observing, you can't beat the Canon image-stabilized binoculars we keep in stock.

Canon

Or it might be a Takahashi.

Takahashi FS-102UH (4" f/8 fluorite/SD on EM-10USD mount)

While many people swear *at* the long delivery times quoted by some manufacturers of premium refractors, most knowledgeable astronomers swear *by* the uncompromised optical quality and fast delivery of the Takahashi refractors we keep in stock.

From the 3.1" **FS-78** to the 5" **FS-128**, we stock Takahashi fluorite/special dispersion glass apochromatic doublet refractors, mounts, and accessories – so we can deliver scopes *fast*. Why wait for up to a year to observe through an apo refractor from another manufacturer? You can be usually be viewing through a truly fine Takahashi apo only a few short days after you order from us. We stock complete Takahashi scopes on USD mounts with dual-axis 50x sidereal slewing, as well as apochromatic optical tubes only to install on your own mount.

We also have the amazing Takahashi **FSQ-106** 4" dual fluorite lens 4-element f/5 apo refractor. It's both a visual scope and 4" focuser astrograph.

Also available from stock is the unique Takahashi **CN-212H** 8.3" reflector that converts from an f/12.4 classical Cassegrain reflector to a very fast f/3.9 Newtonian for visual observing and astrophotography.

If you want something bigger, 6" doublet and triplet apo optical tubes and complete scopes are available on a special order basis.

If you want an apo, and want it now, it's Takahashi from ***astronomics***.

It might be this 5" Meade DS127EC computerized reflector.

Meade 5" DS127EC, with dual axis drive and hand control **$499**

The new Meade DS scopes take the guesswork out of finding deep sky treasures for the astronomy newcomer. They range in size from a 60mm refractor to the 5" f/8 **DS127EC** to the left. Each DS series scope we stock comes complete with #492 dual axis DC drive motors and a hand control for electronic command of the scope's motion. Each DS scope also allows you to add an inexpensive optional Autostar computer to automatically slew the scope to deep space objects and track them flawlessly. The #495 Autostar at $\$99^{95}$ has a database of 1586 objects, while the $\$149^{00}$ #497 Autostar has 14,487 objects and is well suited to the 5" light-gathering of the DS127EC.

For a fully-computerized telecope that will take you on a first-class tour of the heavens, but won't break your bank account, it's hard to beat the new Meade DS scopes we stock.

> Again I wanted to thank you for all of your help. You have another customer for life. You told me what I needed and what I did not. That means a lot when you make a major purchase like this. You all are a first rate professional company. Keep up the good work and thanks again.
>
> **Customer Quote of the Month #93**

Dozens of economy scopes for the star-gazer on a budget!

Celestron Tabletop 76 **$99**

Celestron FS114S **$199**

While we're known for carrying premium optics – from Questar, TeleVue, Takahashi, and more – not all of our scopes are budget-busters. We have eight telescopes priced between $99 and $249, another nineteen priced between $250 and $499, and yet another nineteen more priced between $500 and $999. All are surprisingly good optically. All are shown in our catalog 99AST. Call us at (405) 364-0858 for your free copy.

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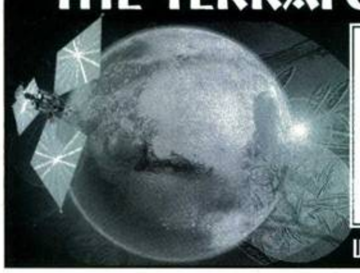

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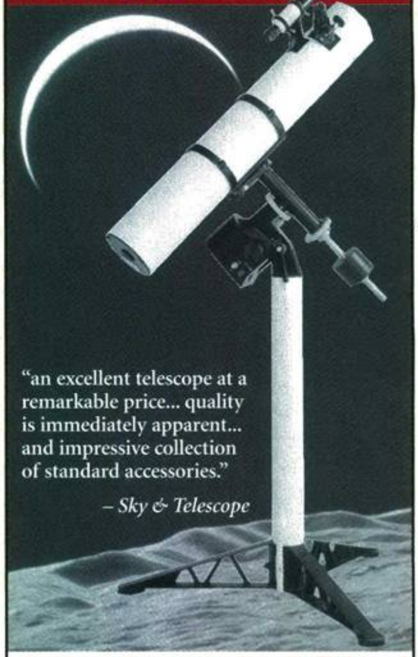

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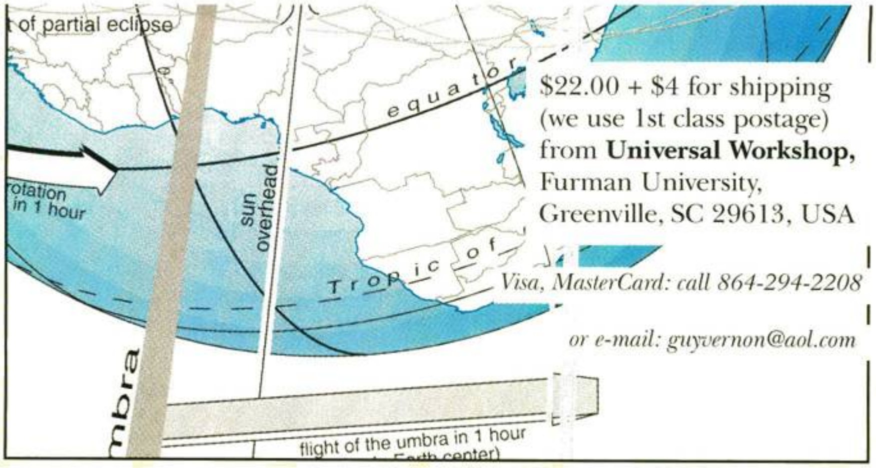

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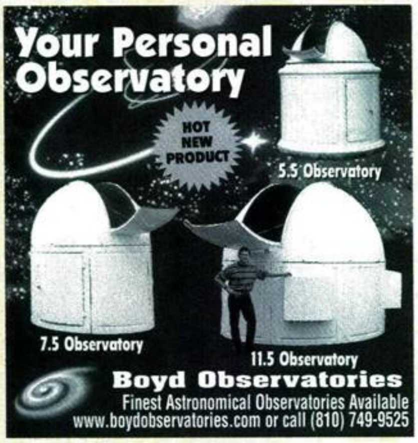
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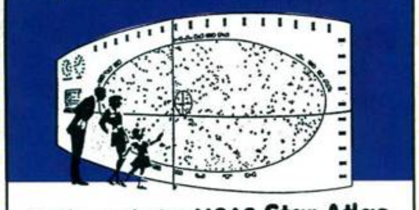

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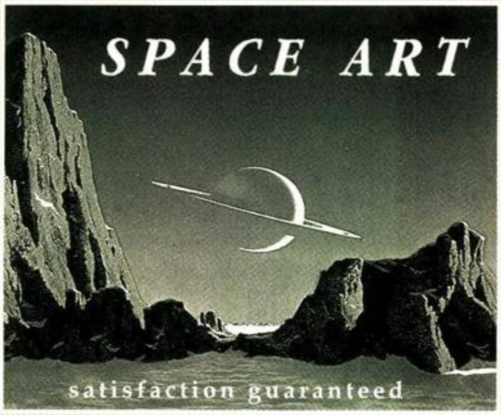

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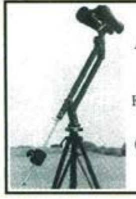

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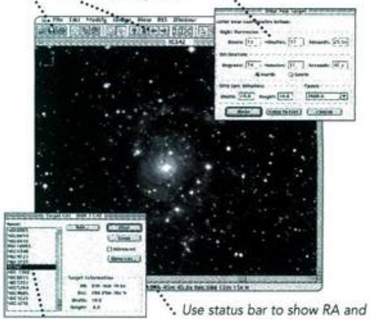

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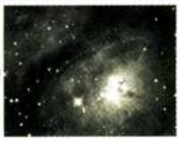

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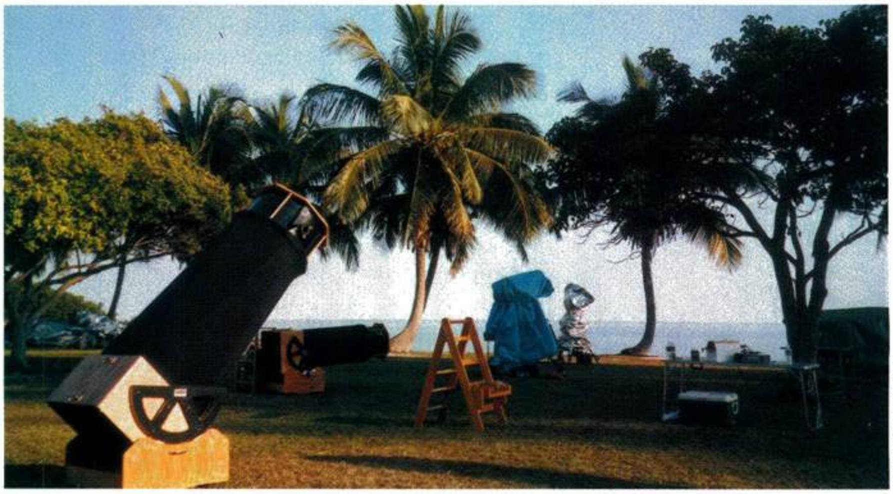
Attendees will witness the arrival of the Mars Polar Lander on the Red Planet's south pole, viewing a giant screen as new images of this unexplored domain are revealed from 35 million miles away. The New Millennium Symposium will feature scientists who create the space missions. Hollywood Pictures will be promoting the release of the movie *Mission to Mars*. A Child's Universe will offer hands-on, interactive activities for kids. Telescopes, educational resources, and information on current and planned space missions will be displayed, along with much more. For information, contact The Planetary Society, 65 North Catalina Avenue, Pasadena, CA 91106; (877) 752–6387; website, www.planetary.org.

A new and improved **Winter Star Party, WSP 2000 A Space Odyssey**, is in the works for **January 31 through February 5**. An exciting line up of speakers includes astrophotographers Don Parker, Jerry Lodriguss, and Jack and Alice Newton, whose photos are often seen in the pages of *Astronomy*; Jack Horkheimer; Stephen O'Meara; and others. This year's attendance is expected to be at full capacity — reserve your space now.

Tippy D'Auria, WSP founder/chairman, reports that the restoration of the Girl Scout camp is progressing. As you may recall, Camp Wesumkee suffered extensive damage from Hurricane Georges, resulting in the cancellation of WSP 1999. More than 450 trees have been planted to replace those damaged or lost to the storm, and several new improvements have been made to the site. Many thanks go to the astronomers who have helped by contributing to the Girl Scout Camp Wesumkee Hurricane Relief Fund. For more information on WSP 2000 and the site restoration, see the Southern Cross Astronomical Society's website, www.scas.org.



Andrea Gianopoulos

The Winter Star Party will once again be held on West Summerland Key in the Florida Keys, January 31–February 5.

NOVEMBER 17, JANUARY 26

The Silicon Valley Astronomy Lecture Series

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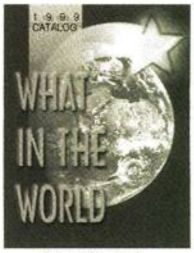

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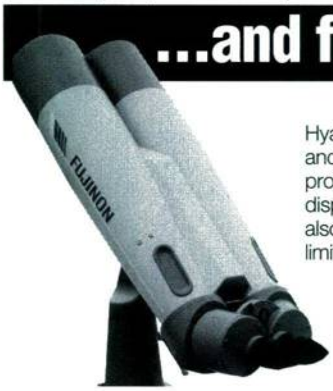

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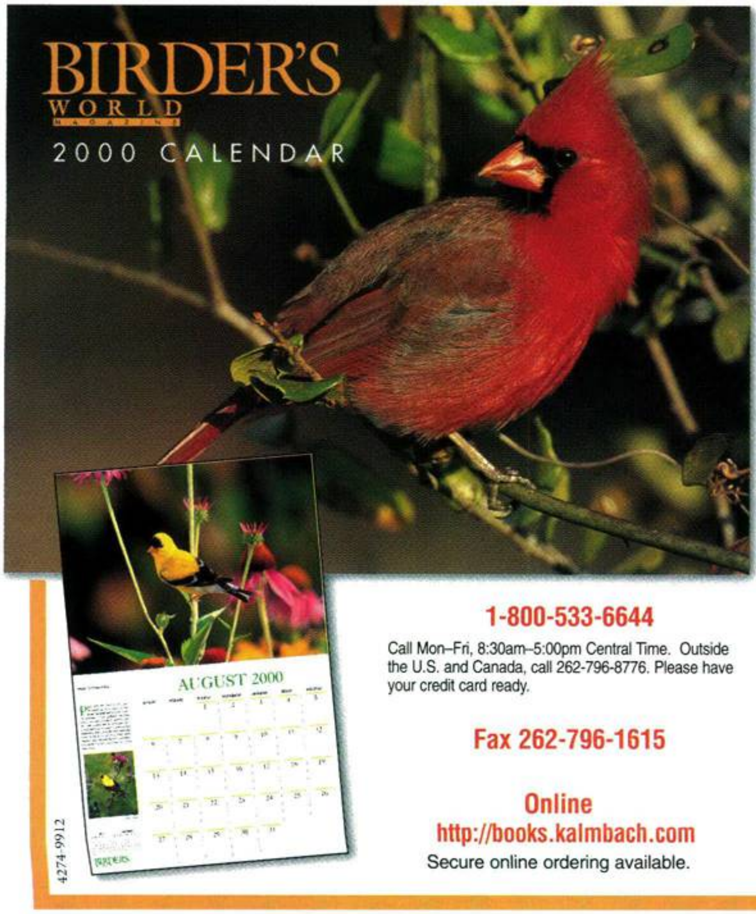

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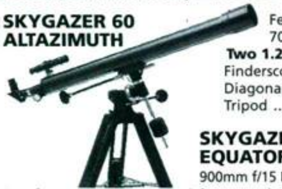

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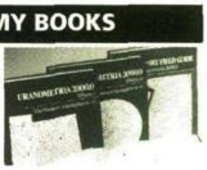

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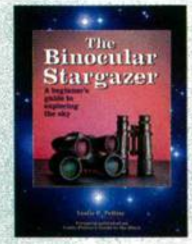

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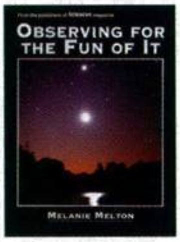

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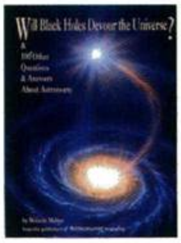

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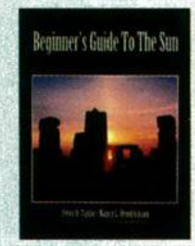

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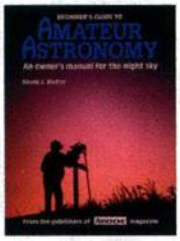
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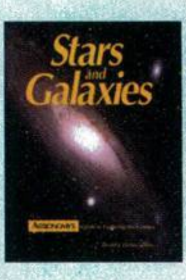

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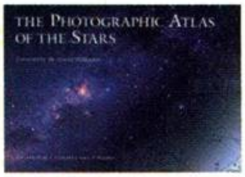

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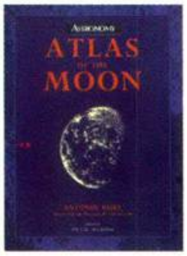

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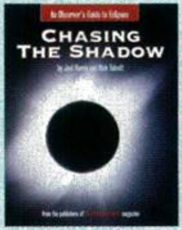

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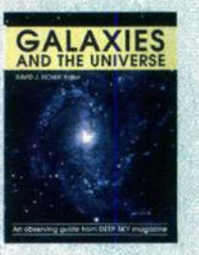
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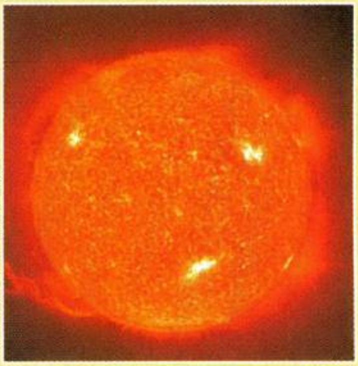
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As the sun reaches a fever pitch of activity in 2000, *Astronomy* takes an in-depth look at our local star. Learn how the sun works, what effects solar activity may have on Earth, why the sun will force us to abandon our planet in a few hundred million years, and the safest ways for you to observe our star.

THE CENTURY'S BIGGEST EVENTS

Sure, Comet Shoemaker-Levy 9 and the 1991 total solar eclipse were awesome sights, but could they crack our list of the top ten sky events of the century?

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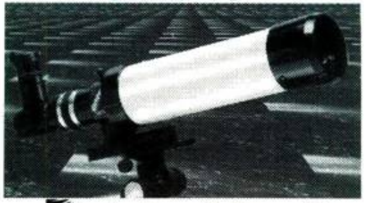

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TOTAL SOLAR ECLIPSE

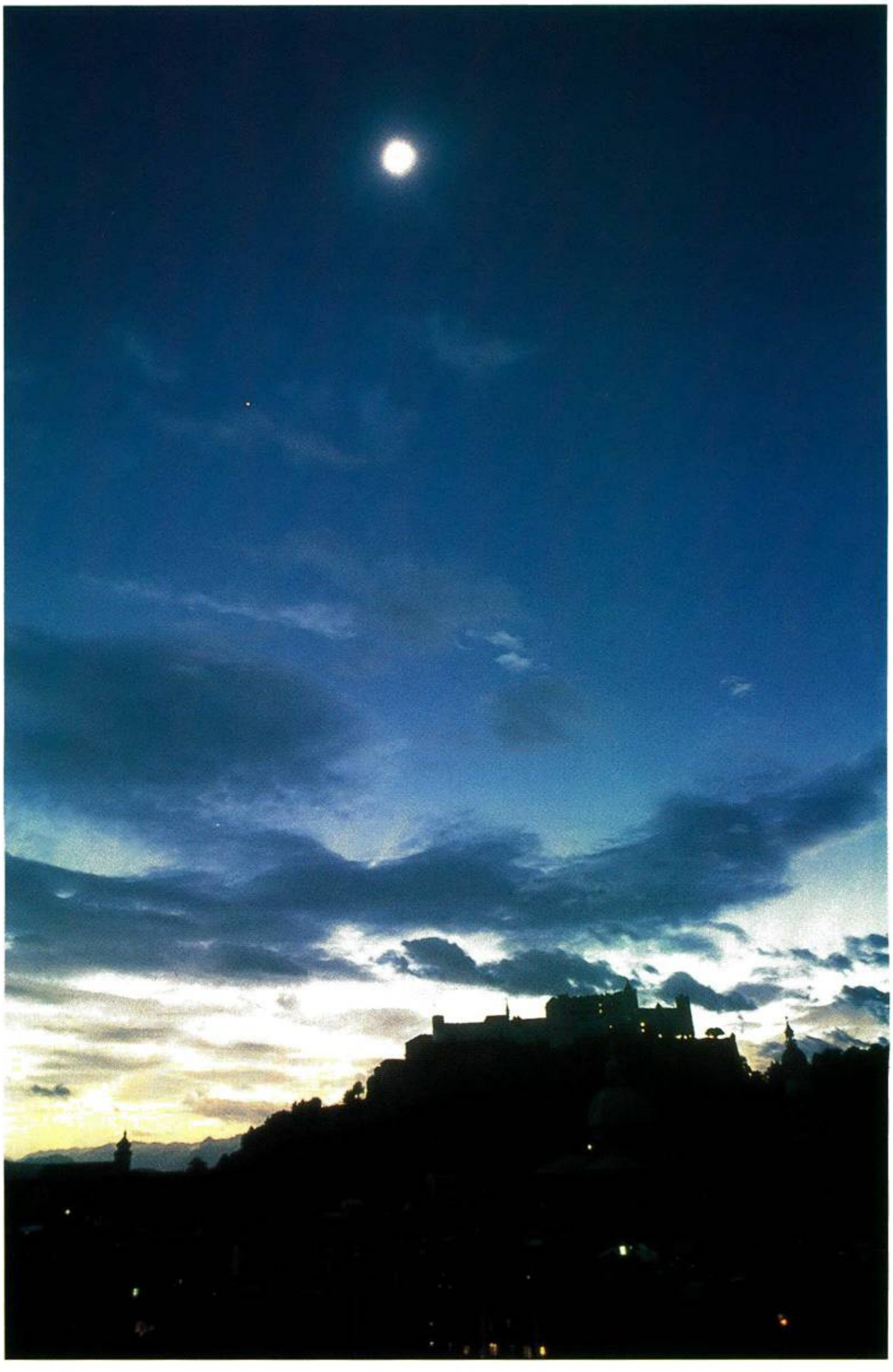
After the Fire

In poetry and prose, eclipse chasers relate their moments in the shadow.

▶ As the sky lightened and darkened and lightened again, I was thinking about how astronomy is not really just about stars and moons and planets, it is about the interconnectivity of it all. Oftentimes, when I am looking through my telescope, I wonder how many people are looking at the same thing. This time there could be no doubt. There would be millions.
— *Pat D'Entremont, Halifax, Nova Scotia, Canada*

Shuttle runs into town,
eating, setting up tripods,
waiting,
First contact, the countdown,
anticipating,
Yells started, the diamond
ring flashed,
Spikes around the sun, the
golden corona, unabashed,
White Venus, reddish promi-
nences, the ring of fire,
All to drink the remarkable
scene, we did not tire,
Success, the joy, the celestial
eclipse elixir,
We had beaten the cruel
weather trickster.
— Eric Flescher, Olathe, Kansas, http://members.aol.com/kcstarguy/blacksun/eclipse.htm

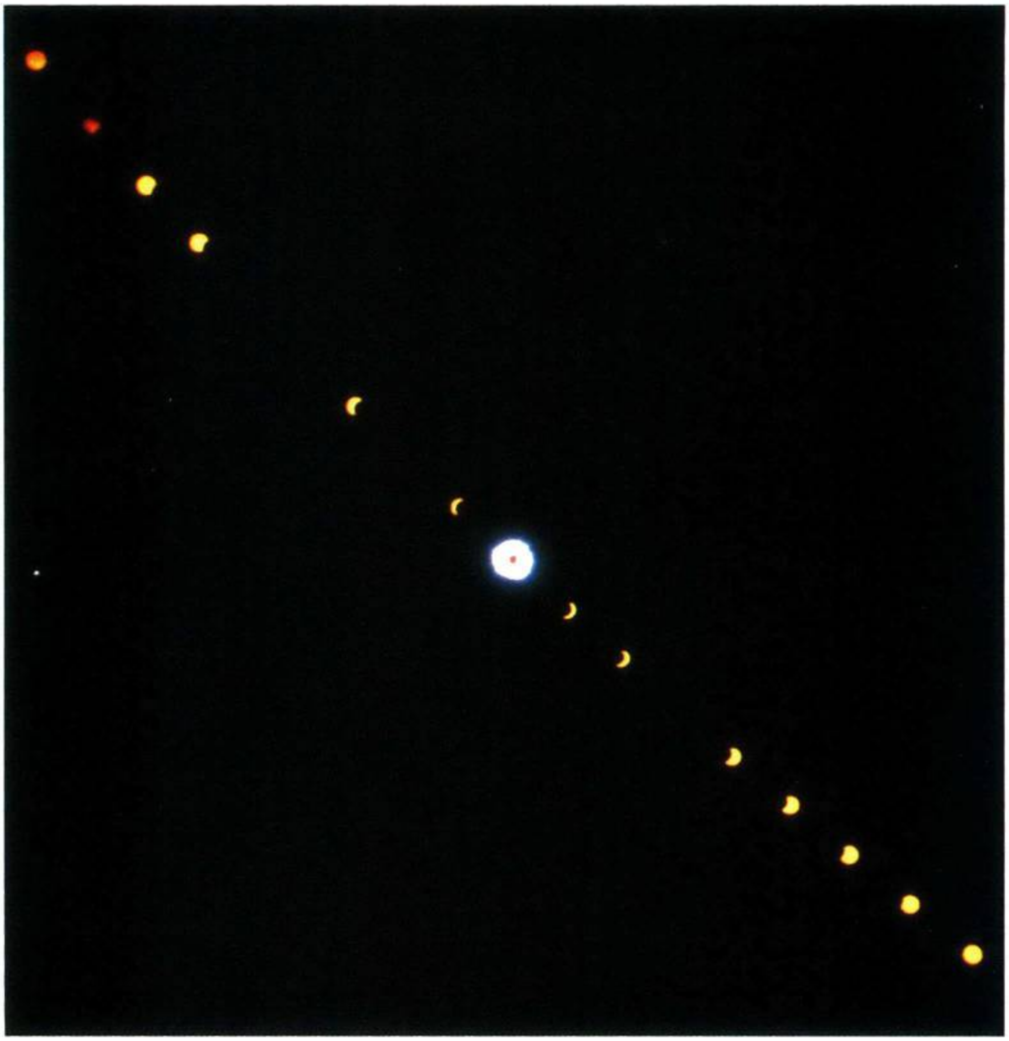
Ann and I had booked for the week to camp on the grounds of the Torquay Boys Grammar School in England. We were surrounded by people who had two things in common, one was astronomy and the



Venus and the Eclipse over Salzburg
DAN FALK

other was that we were all going to be woken by the sea gulls at 5:00 A.M. On eclipse day the sky was cloudy. With about two minutes to go before totality, the sky opened up slightly to show us the last few moments before the sun disappeared behind the moon. But then, 14 seconds before totality, a big dark cloud passed over and blotted out everything. We saw the moon's shadow racing over from the direction of Paignton. As it hit us, all went quiet: no cars, no birds, nothing. It was as if the world had held her breath for a few seconds, then a wave of emotion passed over the field and people started to cheer. The feeling was indescribable. — *Andrew Davies, North Devon, England*

Things heated up as the sun cooled down. People were pretty excited by looking at the ever decreasing disk of sun. Around 98 percent eclipse, the birds in the sky got confused — they started flying in circles, knowing that something was going wrong, very wrong. The sky got pretty dark then. People became excited, expecting to get a glimpse of a sky with a hole in it. And then . . . totality! I was gripped by the sight, bewitched by the darkness that laid upon me, trying to get as much of the totality inside my naked eyes as possible. I placed a tape recorder in the middle of the crowd. It recorded every cry, every clap, every expression. Perhaps the best one was made by a lady sitting near the recorder. Somewhere near totality she said, "Allllaaaaahhh!" — *Omer Bin Abdul Aziz, Lahore, Pakistan*



Clouds Produce Hit and Miss

ALBERTO LEVY

(35mm lens at f/8, Fujichrome Velvia film)

Temporary Night

MICHAEL KOBUSCH

(30mm fisheye lens at f/5.6, Kodak Porta 160 film, 1-second exposure taken from Kecel, Hungary)

Partial Eclipse in Sunrise

RAYMOND P. MAHER, JR.

(400mm lens at f/5, Fuji Superia 400 film, 1/500-second exposure taken from Mount Desert Island, Maine)

The White Tower Eclipse

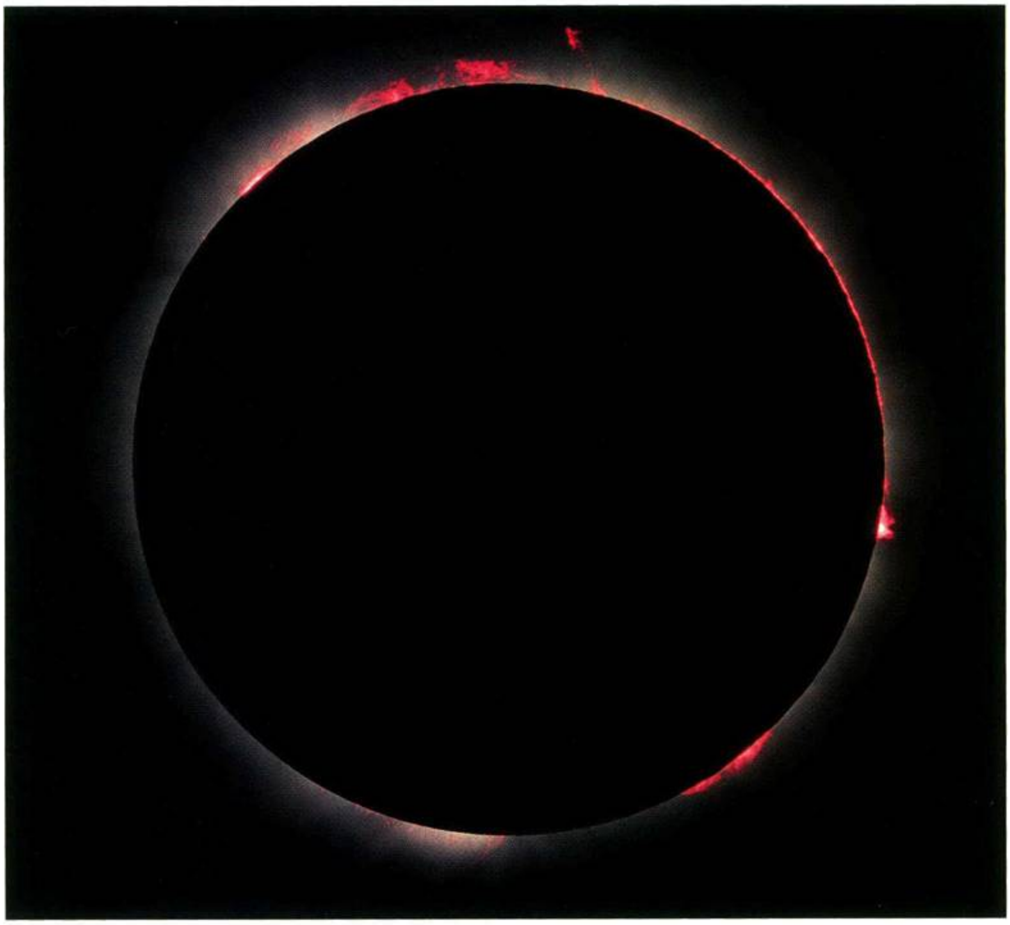
ANTONIOS PANTELIDIS

(Fuji Velvia film, double exposure taken from Thessaloniki, Greece)

(left to right: Shawn Mitchell, Paul Evans, Bill Thurlow, John Jarvo, Clint Shannon, Ted Brekelmans, David Lane, and Ian Anderson)

Imagine the delight and anticipation of seven members of Canada's Royal Astronomical Society when they discovered that the beginning of the August 11, 1999, eclipse started only 230 miles away and could be seen easily and inexpensively! In February 1998, Clint Shannon booked a twin-engine Piper Navaho 8-seat plane with large windows. On eclipse day we met with the pilot, Ted Brekelmans, at 3:30 A.M. to agree on last minute details and be interviewed by CBC-TV. At approximately 4:30, we took off. The stars were shining. I gave out protective glasses to all onboard, including the pilot. We enjoyed the gradual appearance of a half-eclipsed sun rising above the clouds. Totality was awesome! The corona was easily visible; the many prominences shot out reddish-orange flames into the corona. After about 56 seconds of totality and the final diamond ring, the plane turned toward Halifax. The cost was $300 Canadian ($200 U.S.) per person, only a small fraction compared to the money spent by those who traveled to Europe.

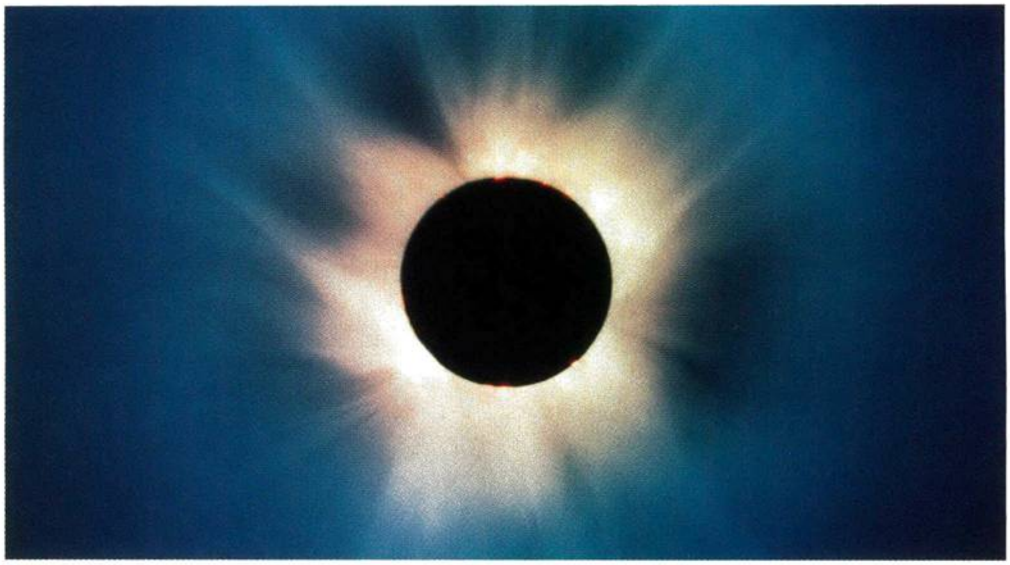
— William Thurlow, Summerside, Canada



Cherry-Red Prominences

JACQUES GUERTIN

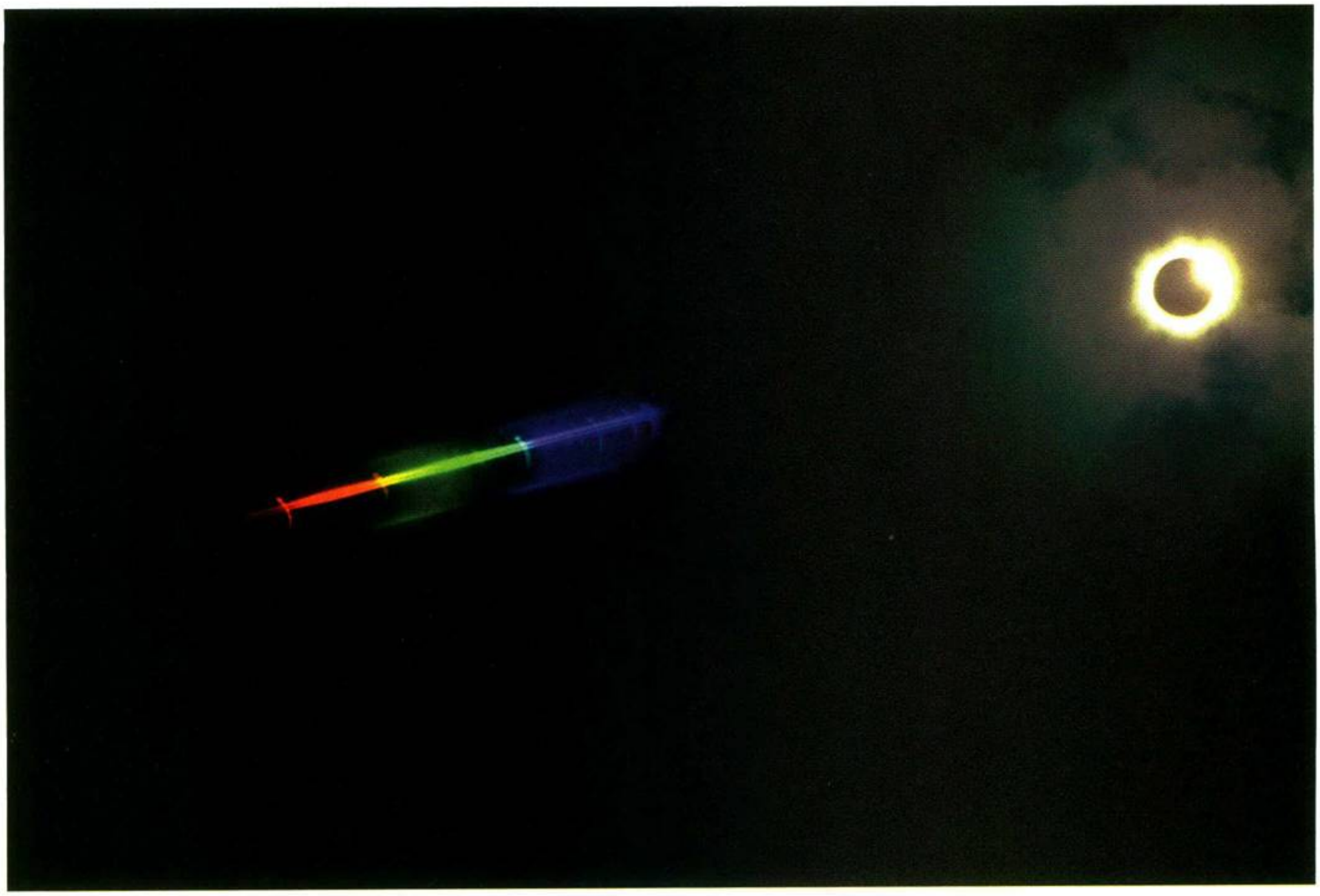
(6-inch Maksutov at f/19, Ektar film, ⅛-second exposure)



The Sun's Aura

ALBERTO LEVY

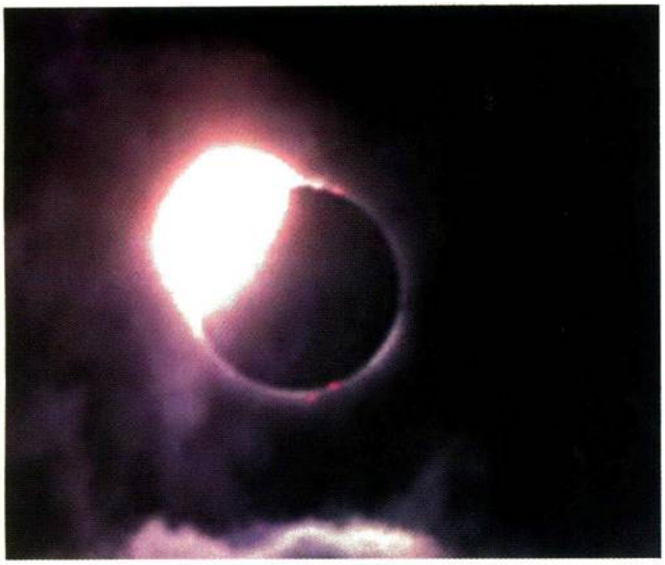
(80mm refractor at f/13, Agfa Optima 100 medium format film, 1½-second exposure)



The Sun's Flash Spectrum

ROBERT AND ELISABETH SLOBINS

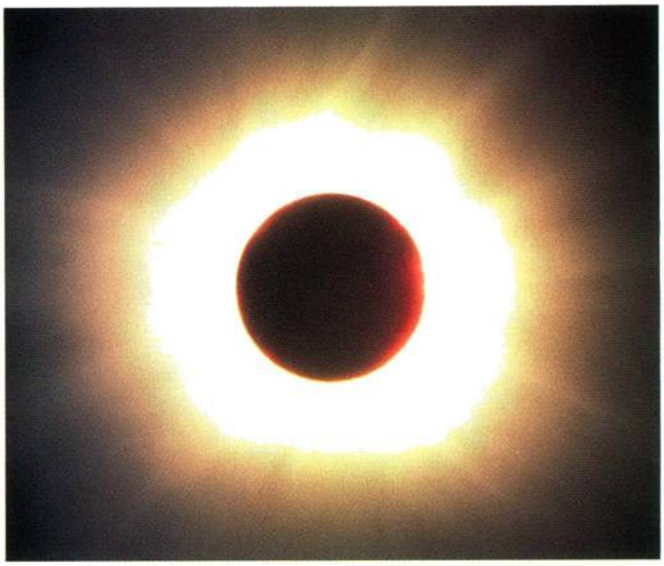
(150mm lens at f/4, Fuji NPS film, 1/60-second exposure)



Clouds Loom Near Sun and Moon

DAVID HAGAN

(500mm f/8 reflector, Fujichrome Sensia film, 1/500-second exposure)



Solar Corona

DAN SCHECHTER

(4-inch f/6 refractor, Kodak Royal Gold 100 film, 1/2-second exposure)

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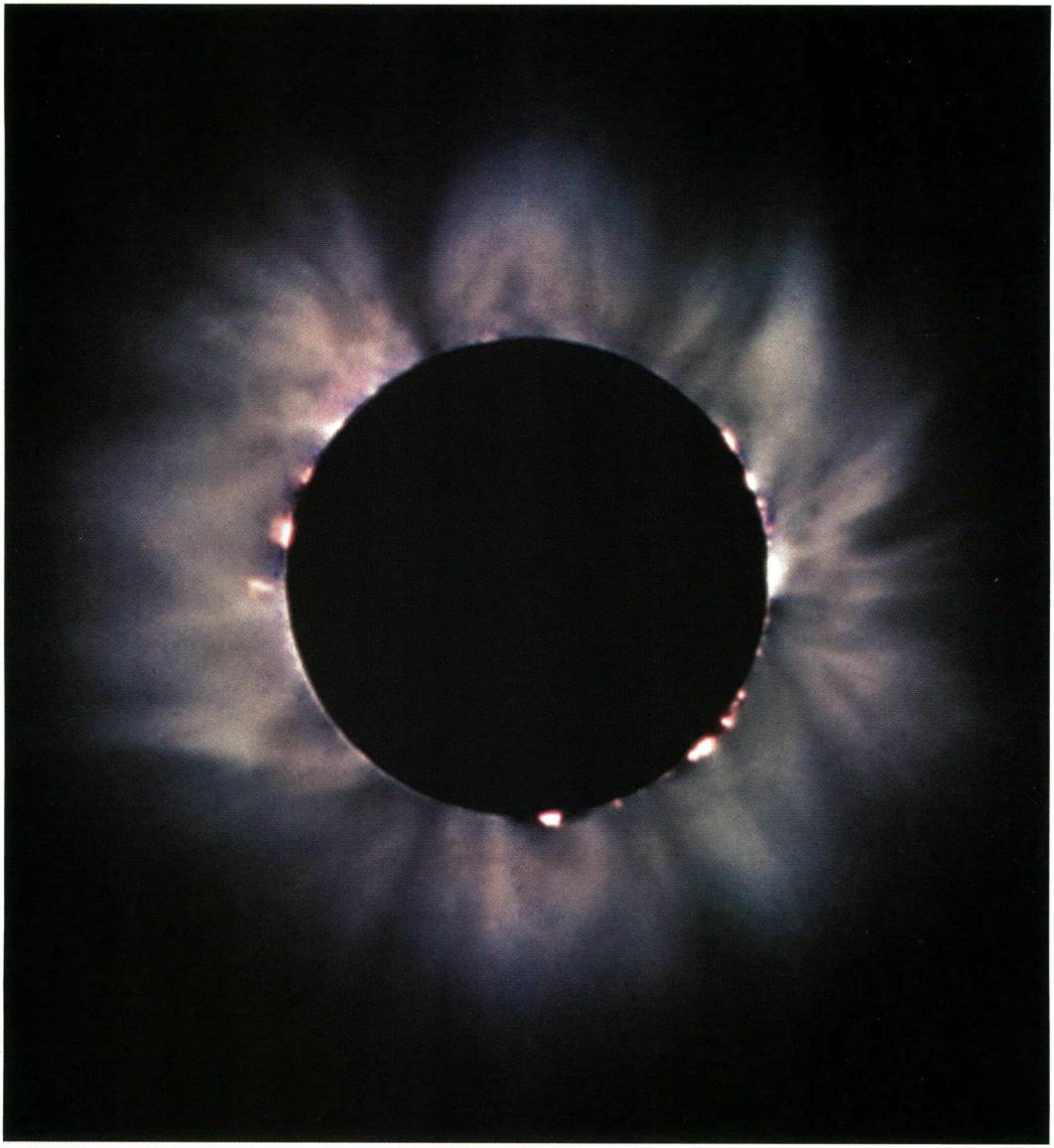

The Eclipsed Sun's Prominences and Corona

MICHAEL SHIN

(4-inch SCT at f/11, Kodak Ektachrome Professional 400 film)

Viewing the eclipse from Europe was a gamble, but Michael Shin saw totality from Dachau, Germany.

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The Whirlpool Galaxy (M51) in Canes Venatici. Photographed with a Meade 10" f/10 LX200 Schmidt-Cassegrain Telescope in southern France by Philip Perkins of Wiltshire, England. Mr. Perkins used two exposures of 120-mins. each on hypered Kodak Ektapress Multispeed PJM-2 film; these exposures were then scanned, digitally combined, and processed to obtain the final image.

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